Sydney Water Inquiry

Fifth Report

Final Report Volume 2

December 1998

Peter McClellan QC

Cataloguing in publication data:

New South Wales. Premier's Department. Sydney Water Inquiry Secretariat. Sydney Water Inquiry. Final Report.

ISBN: 0 7313 3073 0 (set)
0 7313 3079 X Vol 1
0 7313 3085 4 Vol 2

1. Water quality - New South Wales - Sydney
2. Water supply - Management - New South Wales - Sydney
I. Title
II. McClellan, Peter QC

628.1099441

For further information please telephone the Sydney Water Inquiry Secretariat

GPO Box 5341
SYDNEY NSW 2001

Tel: (02) 9228 5586
Fax: (02) 9241 5434

URL: http://www.premiers.nsw.gov.au/pubs.htm

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Executive summary

The contamination of Sydney's water supply was unique in a number of respects. The reported levels of *Cryptosporidium* and *Giardia* in both raw and treated water were significantly higher than levels previously recorded. The reported levels caused the international scientific community to doubt the accuracy. The Inquiry was conducted during the events which followed the initial contamination. This meant the

management of the later events benefited from the knowledge gained from the initial problems. It ensured an effective public health response.

Most reported contamination events in other parts of the world appear to have been identified following an outbreak of illness within the community. This was not the case in Sydney where contamination was identified as part of a routine monitoring program which enabled a response before any illness had been reported.

Investigation into the cause of the contamination has proved difficult. However, this report identifies the factors which contributed to each of the events and makes further recommendations to improve the quality of the water supply.

Cryptosporidium has only recently been identified as a significant health issue in water supply systems. Until 1984 *Cryptosporidium* had not been identified in water. In recent years there have been a number of incidents resulting in health problems in various parts of the world. Following each major event there has been some form of investigation.

Unless the contamination was confined to some obvious source, usually within the distribution system, most of the investigations have proved inconclusive. This is primarily due to the limits of scientific knowledge in various areas.

There is no general agreement about the efficiencies of water filtration in removing *Cryptosporidium* and *Giardia*, the appropriate methods of testing for the parasites, or the health consequences if they are present. It is clear that the developing science has advanced beyond the capacity of the health authorities to provide an effective response. This is not to criticise the health authorities, but rather to emphasise the need for the scientists to ensure that developments which they make are capable of interpretation and are communicated effectively to health administrators.

Many issues have been raised during the Inquiry. Because contamination continued to occur as the Inquiry progressed, the significance of some issues diminished and others became more important. Many of the issues have now been resolved although a number remain and will require continuing research.

I have provided three interim reports. I have also reported separately in relation to the tender process and contract for the Prospect Water Filtration Plant.

The First Interim Report considered the possible causes of contamination of the water supply. It was published after preliminary inquiries had been made. The Second Interim Report looked in detail at the management of the First Event. That account of the First Event is incorporated into the Final Report together with some changes due to further information which has been obtained.

The Third Interim Report provided an authoritative discussion of the health issues which have arisen from the contamination, considered the quality of the catchment waters and addressed the need to create a new body to manage the catchment. The Government responded to the first three Interim Reports by introducing comprehensive legislation which has since passed through the Parliament. As the

issue of the Sydney Catchment Authority has now been resolved it has not been further discussed in the Final Report.

The Third Interim Report also commented critically on the laboratory work which had been undertaken during the events and recommended that an independent laboratory be engaged to undertake the necessary testing for health and regulatory purposes. This recommendation has been accepted by the Government.

This Final Report provides an analysis of all of the issues raised by my terms of reference. Because of the many uncertainties in the science it is not possible to be definitive in a number of areas. The difficulties have been identified and where appropriate I have recommended further research.

The initial contamination event caused great concern among the relevant authorities and the general community. Fortunately, there has been no identifiable illness. However, the degree of alarm has emphasised the need for continuing education and public disclosure of information about the quality of Sydney's water.

This need extends to information about the protection and treatment of the water supply and the terms of any contractual arrangements designed to protect it. Although there may be good reason for restricting information in limited areas because of its commercial value, there is a competing public interest in the community being aware of the conditions under which the water supply is protected. The private sector must accept that in many cases the entitlement of the public to know contractual details must prevail over any private commercial interest. Of course, it is necessary in considering these questions to remain conscious of any impact upon the private sector's preparedness to tender for government projects if commercial information is released.

History of the events and their management

The Second Interim Report provided a detailed account of the First Event which occurred between 21 July and 4 August 1998. The Second Event commenced on 24 August 1998 and the third commenced on 5 September 1998. The Second Interim Report identified some problems in the management of the First Event, particularly within Sydney Water but there were also some problems within NSW Health. The management of the Second and Third Events was satisfactory.

It is apparent that the level of understanding of the science and the health consequences of *Cryptosporidium* and *Giardia* in the water supply, by both Sydney Water and NSW Health, has significantly increased due to the information brought forward since my Inquiry began. Experiences of other waterborne occurrences of *Cryptosporidium* and *Giardia* where there were deaths strongly endorses the need to take a conservative health approach when there are positive test results. I am satisfied that the decisions to introduce boil water alerts were appropriate.

Sydney Water has thoroughly reviewed its incident management procedures. It has also carried out an extensive debriefing in relation to the events. Sydney Water and

NSW Health have revised the terms of their Memorandum of Understanding (MoU) relating to incident management.

I strongly endorse the actions of Sydney Water and NSW Health to improve their incident management procedures. Sydney Water has taken action to ensure that the lessons learnt will be applied in the future. Implementation of the recommendations of the review and the revised MoU should significantly improve the organisations' capability and preparedness for managing future incidents.

Cause of the contamination

It is now apparent that the catchment waters for much of Sydney's water supply contain significant sources of *Cryptosporidium* and *Giardia*. Heavy rains in the catchment which followed a period of significant drought carried the organisms into the stored waters of Warragamba and other dams.

Although the rainfall at the time of the First Event was not as significant as the later events, the treatment plant at this time experienced a number of operational difficulties which would have allowed pathogens to pass in greater than usual numbers. There is also a possibility that some pathogens were concentrated in parts of the treatment plant and released during the events, although I doubt whether any of these possibilities provides a complete explanation.

There has been considerable debate about the quality of the laboratory work undertaken by Australian Water Technologies (AWT) throughout the events. Although it has been agreed that it correctly identified *Cryptosporidium* and *Giardia*, the actual numbers remain in dispute. The high and extremely high levels of pathogens detected in some parts of the distribution system in the First Event have not been adequately explained. Australian Water Services (AWS), the operator of the Prospect plant, argues they were mis-identified by AWT and some may have been algae. AWT accepts that if the particles were correctly identified it was likely they had accumulated in parts of the system where they could be released by hydrant flushing. The scientific uncertainties and problems with the laboratory make it impossible to conclusively resolve this matter. However, Sydney Water is continuing to conduct research into parasites in biofilm and recent results tend to confirm that *Cryptosporidium* and *Giardia* will accumulate within the system.

The Second and Third Events were caused by pathogens which were washed into the catchment waters and passed through the plant when it was required to treat highly turbid waters. At this time contaminated water accumulated at a specific level of water density, called a thermocline, which had formed in the dam and from which water was intermittently drawn into the offtake. The absolute numbers which passed cannot be determined and as a consequence it is not possible to assess the performance of the plant during the events. It may have been that the level of organisms in the raw water was so great that the plant, although operating efficiently, allowed high numbers to pass. It may also be that, for reasons not presently understood, the plant allowed *Cryptosporidium* and *Giardia* to pass through given the extraordinary conditions which were experienced. I have recommended that research,

particularly with the prototype plant, be pursued in an attempt to resolve these matters.

The efficiency of the filtration plants

Apart from the North Richmond, Orchard Hills and Nepean plants, Sydney's water is treated by plants which utilise direct filtration techniques. Direct filtration was chosen instead of conventional filtration, which is believed to be more efficient, because of the assumed quality of Sydney's catchment waters. It has been suggested that the filtration plants, including Prospect, should achieve a high efficiency in removing *Cryptosporidium* and *Giardia*. Claims are made that they can remove in the order of 99.9% (3 log) or greater.

Unfortunately, the science related to *Cryptosporidium* and *Giardia* and water treatment is not sufficiently mature to be able to measure the efficiency of the Prospect plant in removing pathogens. To assist in the task I asked that the prototype plant be recommissioned and attempts made to simulate relevant events in the plant. These tests demonstrate high levels of efficiency of pathogen removal up to 99.999% (5 log). However, there are limitations on the utility of these conclusions because it is not possible to replicate the real situation. I am not satisfied that the test results can be used to verify the efficiency of the plant during the recent events. Further research is required.

The science - a picture of uncertainty

I reported in the Third Interim Report on the uncertainties which complicate the science related to *Cryptosporidium* and *Giardia* and water treatment. In the weeks since I provided that Report, extensive further research has been undertaken. It is apparent that although some knowledge of the detection and health consequences of the pathogens is available, the limitations of that knowledge make it difficult to manage the related health issues.

In my Third Interim Report I recorded a number of problems which have been identified with the work of AWT. I also recommended that an independent laboratory undertake the relevant work to provide the information necessary to manage health issues and regulate the quality of the water supply. AWT has now made a detailed submission in relation to the earlier findings and I have modified some of my conclusions in response to the submission. However, I am satisfied that serious difficulties remained in the work undertaken by AWT during the events and I doubt all of the reported results are reliable. Although *Cryptosporidium* and *Giardia* were correctly identified, the levels reported by AWT cannot be verified.

The debate about the quality of the work of AWT and the fact that it is a wholly owned subsidiary of Sydney Water confirm the need for an independent laboratory to undertake the relevant sampling and testing. AWT should continue to undertake work in relation to pathogens and other matters for Sydney Water and other clients. Unless an independent laboratory is utilised for health and regulatory purposes, AWS and regulatory agencies will have no confidence in the data and the public may continue to doubt the reliability of any information relating to results. It would be unacceptable

if, in any future incident, the plant operator disputed the fundamental laboratory data which is essential to manage such events.

Health issues

I reported in the Third Interim Report that it was most unlikely that any person suffered illness because of ingesting *Cryptosporidium* and *Giardia* during any of the events. I was satisfied that the surveillance techniques used by NSW Health were adequate to substantiate this conclusion.

NSW Health has now developed an appropriate interim protocol which will operate during any future contamination event. The protocol was prepared in consultation with Sydney Water and reflects world's best practice.

This Final Report identifies the necessity to ensure the public is better informed about the possibility of *Cryptosporidium* and *Giardia* in the water supply and the likely health consequences. In particular, NSW Health must issue further advice to the immuno-compromised community making clear the potential risks from *Cryptosporidium* in water and other sources. The advice should state that all tap water that might be consumed by immuno-compromised persons should be brought to the boil before use. This advice is consistent with international best practice.

Because of the continuing scientific uncertainty about the relationship between *Cryptosporidium* and *Giardia* in the water supply and illness, and the potentially fatal effects of *Cryptosporidium* on immuno-compromised persons, I believe a conservative response must be taken. This advice must be accompanied by a clear and consistent public education campaign about the risks of *Cryptosporidium* and *Giardia*.

It would be inappropriate, considering the present level of scientific knowledge, to provide mandatory health related standards.

Publication of test results

During the recent contamination events, Sydney Water initiated the publication of all treated water parasite test results on its Internet Web site. NSW Health took responsibility for reporting any positive results directly to the public via the electronic media.

There is an expectation that results of tests for *Cryptosporidium* and *Giardia* will continue to be made public. In my view the public must be informed of future instances of contamination and any risks to the drinking water supply. All information about water quality should be published.

Sydney Water's practice of posting all treated water test results on its Web site should continue and NSW Health should continue to publicise any results with potential public health implications.

Future regulations

In this report I recommend a strengthening of the regulatory framework controlling the operations of both Sydney Water and the Sydney Catchment Authority to increase the accountability of these bodies to the Government and the community. I suggest that the Operating Licence be replaced by an improved licence which is developed through a process of public consultation, and that the role and structure of the Licence Regulator be modified to enable it to undertake a stronger and better defined role in the management of Sydney's water. The Report also highlights the need to improve the mechanisms for responding to complaints about Sydney Water.

A mandatory water quality level for *Cryptosporidium* and *Giardia*?

The present inadequate understanding of *Cryptosporidium* and *Giardia* and the limits of the relevant technology make it inappropriate at present to provide regulations which define maximum operational levels of *Cryptosporidium* and *Giardia* in the water supply to protect public health. However, significant developments are occurring, in particular in the United Kingdom, which if proven, may provide a mechanism to prescribe operational standards.

It is appropriate to give water suppliers time to evaluate their position and to undertake appropriate cost/benefit analysis before a mandatory standard is considered.

I recommend that a process begin immediately to review the effectiveness and consequences of applying an operational standard. The Government should review the position with a view to imposing an operational standard at the end of 1999 or as soon thereafter as may be appropriate. This review should be informed by the work of the National Health and Medical Research Council (NHMRC).

Monitoring

The difficulties in detecting *Cryptosporidium* and *Giardia* make it complex to design adequate monitoring regimes. However, I am satisfied that it is necessary to implement event and research sampling with a view to improving the understanding of the general quality of Sydney's water and to assist in managing any potential contamination events. A monitoring program should have clear linkages to public health and operational decisions.

I have endorsed a revised monitoring program which has been developed jointly between Sydney Water, NSW Health and the EPA.

Future improvements

The Parliament has recently legislated to create the Sydney Catchment Authority. The Third Interim Report identified steps which should be taken to alter the management of stored water and improve the quality of water entering the treatment plant

following significant rain events. This Final Report provides an indication of steps which should be taken to strengthen the barriers to contamination of the water supply. These include the utilisation of Prospect Reservoir and effective monitoring at critical points in the system. The Report also identifies changes which could be made to optimise the performance of the Prospect plant.

I have also identified the necessity of maintaining the distribution system to ensure the delivery of high quality water to consumers.

Augmentation of the treatment process

One immediate response to the contamination events was the suggestion that the treatment plant should be augmented by some further treatment process. This could be done by ozonation at a cost of up to $300 million or possibly by some form of membrane filtration at a cost of up to $600 million. The latter technology has not been proven on plants as large as Prospect.

I do not believe that expenditure of this magnitude can presently be justified. If the changes proposed in the Final Report to the management of the raw water and refinement in the operations of the plant prove effective, future contamination of the water supply will be minimised. Capital expenditure of the identified magnitude could only be justified if future contamination by organisms which are infective is likely to occur. Unless the further research which I have recommended concludes that augmentation is necessary, available capital would be more prudently allocated to the provision of public health or other community facilities.

Future operation of the plant

The report on the contract (the Fourth Report) details the contractual provisions and requirements which control the parameters required for water quality. It is apparent that the various parameters relating to turbidity, coagulation and filter operation could be modified to ensure the most efficient operation of the plant. I recommend that these matters be considered with a view to negotiating more rigorous operating conditions for the plant.

Research

I have emphasised throughout the Inquiry the many areas of scientific uncertainty. There is a real need for detailed research in a number of areas. Future management of public health issues requires an increased understanding of treatment plant effectiveness, management of the water cycle and the health effects of various forms of *Cryptosporidium* and *Giardia*. The Final Report makes recommendations for research in a number of areas. This research must be supported by adequate funding.

The future

The present level of scientific knowledge makes it impossible to identify all the factors which have contributed to the contamination events and to meaningfully

predict the likelihood of its recurrence. However, after the experience of the recent events and the implementation of the various proposed management changes, I am confident that Sydney's water supply can be managed to minimise all reasonable risks to public health.

The presence of contamination in Sydney's water supply understandably caused great concern within the whole community. As this report makes plain, the Government and the Parliament have fully supported the Inquiry process and endorsed the outcomes recommended in the various reports. There are some issues which remain to be considered and I have every confidence they will also be addressed and dealt with in an appropriate and bipartisan manner.

I am also satisfied that the revised interim protocol provides the appropriate mechanism for managing any future contamination events. The protocol has been prepared following extensive consultation between Sydney Water, NSW Health and Dr Fricker of Thames Water, who assisted the Inquiry.

Chapter 1: Introduction

The Government responded to the contamination of Sydney's water supply in a number of ways. In an endeavour to identify the problems an Inquiry was formed. I was appointed its Chair on 5 August 1998. The terms of reference of the Inquiry are detailed below.

"Review the procedures and actions taken by Sydney Water and the Health Department

New South Wales Government has commissioned an independent review of the procedures and actions taken by Sydney Water and the Health Department following the outbreak of *Cryptospoidium* and the micro-organism *Giardia* in Sydney's water supply.

The review will provide an initial interim report into the possible cause of the contamination and procedures in alerting the public.

Terms of Reference

i) determine when the contamination occurred and when it was discovered by Sydney Water;

ii) identify the source of the contamination;

iii) identify any equipment, systems or management failures that may have led to the contamination;

iv) determine whether Sydney Water's monitoring and disinfection systems are adequate;

v) determine whether the current arrangements for water treatment are appropriate;

vi) determine who is responsible for the current arrangements and whether their actions were appropriate;

vii) determine whether Sydney Water and the Department of Health acted as swiftly as possible to inform the Government and the community of the contamination;

viii) determine whether communication between Sydney Water and the Department of Health on the issues was effective;

ix) recommend any changes or improvements to the procedures for monitoring water quality and informing the Government and the community of any problems in Sydney's water supply;

x) report on any other relevant matters including the accountability of Sydney Water to the Government and the community."

The terms of reference were extended on 16 September 1998 to amend paragraph (x) to provide:

"x) report on any other relevant matters including:

- the accountability of Sydney Water to the Government and the community;
- matters referred to the Inquiry by Parliament, the Premier, or the Minister for Urban Affairs and Planning; and
- the contamination events which occurred in July, August and September of 1998, and any other contamination events which occur prior to the delivery of the final report of the Inquiry."

Summary of events

Evidence of contamination in Sydney's water supply by the organisms *Cryptospoidium* and *Giardia* was first detected on 21 July 1998. Under the existing arrangements, Sydney Water informed NSW Health of the event. The levels did not raise health concerns. Low levels of *Cryptospoidium* and *Giardia* are commonly found in water supplies throughout the world.

Sydney Water continued testing the water at various points in the water distribution system and by 26 July, high, and in some cases extremely high, readings were reported. On the afternoon of 27 July a boil water alert, a common response to contamination, was issued for the eastern CBD. The incident was treated as localised.

Results showing low levels of contamination were obtained on 28 July and in the early part of 29 July. But then, late in the afternoon and early evening, high readings became available from samples at the Prospect Water Filtration Plant, the Potts Hill reservoir and some locations further down the system. A decision was made that evening, after consideration of whether to alert the area of Sydney supplied through Prospect (up to 80% of the Sydney residents), to issue a new boil water alert confined to the area serviced by the Potts Hill reservoir generally the areas south of the harbour. This is described as the First Event.

On 30 July high readings were obtained from water sampled at Palm Beach. A Sydney wide alert was declared. The Government announced the formation of an expert panel to advise on water safety. Public concern required Ministerial response and the Hon Craig Knowles, Minister for Urban Affairs and Planning, assumed the task of keeping the public informed until the crisis passed and the water supply was declared safe on 4 August.

High readings were, however, again measured at the distribution chamber downstream of the Prospect plant on 13 August. Testing has shown that most of these organisms were likely to be dead. Further positive, although lower, readings were obtained on 14 August. The expert committee considered both readings but decided against the issue of a boil water alert. However, the positive tests confirmed that there was a continuing source of pollution.

Further contamination was identified on 24 August. This led to an extended boil water alert which is described in this report as the Second Event. The alert was progressively being lifted when further contamination was reported on 5 September. A two-week boil alert was instituted. This incident is described as the Third Event. The alert was lifted on 19 September at 11am.

The Inquiry's reports

The Inquiry has produced five reports:

- First Interim Report, Possible Causes of Contamination;
- Second Interim Report, Management of the Events;
- Third Interim Report, Assessment of the Contamination Events and Future Directions for the Management of the Catchment;
- Fourth Report, Prospect Water Filtration Plant Tender Process and Contract Arrangements; and
- Final Report.

Chapter lists of the previous reports are in the appendices.

The First Interim Report

The Terms of Reference required me to provide an Interim Report within 10 days on the possible cause of the contamination and the procedures to bring the matter to the attention of the public.

It was not possible to complete a report on the management of the events within this timeframe. I believe it was critical that all parties had the opportunity to put before me all the material which is relevant to understanding their respective positions in the management of the events and to ensure that everyone was treated fairly. The management of the incident was therefore assessed in a separate report.

The First Interim Report which discussed possible causes of the contamination was released in August 1998. It noted that, while levels of contamination were apparently high, it was believed that many of the organisms were either dead or decaying, and not infective. There was no identifiable increase in disease recorded at that time. The Report discounted a localised contamination event and the Potts Hill reservoir as the source of pollution. I commissioned further studies to attempt to determine the cause.

The Second Interim Report

The Second Interim Report was completed in September 1998 and focused solely on the management of the events. The Report revealed a number of significant problems, notably delays by Sydney Water in alerting the public to potential health risks and the fact that the decision to initially limit the alert to the Potts Hill system, rather than a Sydney wide alert, did not reflect appropriate concern for public health. It reported that Sydney Water failed to respond to the initial contamination by implementing an adequate testing regime. The Report concluded that Sydney Water's executive decision making was inadequate and that it seriously failed to discharge its obligations to Minister Knowles. Some failings were also revealed within NSW Health, confirming the need for adequate management guidance for future significant contamination events and a critical examination of procedures to communicate health warnings to the public.

The Third Interim Report

The Third Interim Report provided a detailed assessment of the contamination events and outlined future directions for management of the catchment. It was released in October 1998. The Report concluded that the main catchment for Sydney's water supply is seriously compromised, not only by the presence of *Cryptospoidium* and *Giardia* but in other respects. I concluded that immediate action must be taken to establish appropriate management and regulatory structures to ensure the catchment is not further compromised and, if possible, existing problems are minimised or removed.

Following the release of the Second Interim Report, the Premier announced that the Government was prepared to create a Catchment Commission and ensure that it was given appropriate powers and adequate resources to protect water quality within the catchment. The Parliament has now legislated to provide for the Sydney Catchment Authority.

The Report provided a detailed account of the scientific problems in identifying *Cryptospoidium* and *Giardia* and the present difficulties in understanding their health consequences. It outlined difficulties identified in the laboratory testing results and the performance of the filtration plants. Further research undertaken during the course of the Inquiry creates doubt about many of the laboratory results obtained during the various contamination events.

The Report recommended the establishment of an independent testing laboratory to provide testing services for all regulatory agencies. The results should be available to both the regulators and the community.

The Fourth Report

The Terms of Reference for the Inquiry also required me to "determine whether the current arrangements for water treatment are appropriate, determine who is responsible for the current arrangements and whether their actions were appropriate". These issues required an examination of the confidential negotiations which preceded the contract for the Prospect plant and the legal advice given to the Board of Sydney Water Corporation.

Although I have received every co-operation from Sydney Water in the investigation, it was unable, for appropriate commercial reasons, to voluntarily give me copies of material that attract legal professional privilege. To overcome this difficulty, I asked the Premier for the powers of a Royal Commissioner to complete the investigation of matters relating to the contract. This request was immediately granted and a separate Report has been completed.

The Final Report

This Report seeks to bring together a response to all of the Terms of Reference, drawing upon the issues identified in my earlier reports and providing advice and recommendations on a number of outstanding matters relating to the performance of the Prospect plant, the future management of Sydney's water supply and the appropriate public health measures.

The Report does the following:

- lists all the Inquiry's recommendations;
- provides a summary of the contamination events;
- outlines the management of the Events;
- identifies the sources of contamination;
- identifies the causes of the various contamination events;
- discusses the efficiency of the water filtration plants;
- outlines the scientific understanding of *Cryptospoidium* and *Giardia* and identifies uncertainties in detection, viability and infectivity as well as problems in the operation of the laboratory;
- outlines the public health impacts of *Cryptospoidium* and *Giardia* and defines future directions for public education and the management of health alerts;
- provides further recommendations to strengthen the regulatory controls applying to Sydney Water and the Sydney Catchment Authority in relation to the protection of water quality, health impacts, public reporting and customer service obligations;
- examines the issues that need to be considered in moving towards mandatory water quality levels;
- recommends new monitoring requirements for *Cryptospoidium* and *Giardia*;

- reviews best practice in the management of contamination incidents and outlines changes to Sydney Water's incident management procedures;
- recommends a comprehensive package of improvements to enhance water quality in relation to catchment management, storage management, operation of the Prospect plant and related matters;
- describes the tender and contract process for Prospect Water Filtration Plant, considers whether the plant's environmental assessment imposed a performance standard for the removal of *Cryptospoidium* and *Giardia*, and addresses certain issues arising from the contract;
- identifies future research priorities to address uncertainties in detection, viability, infectivity and water treatment processes; and
- provides a comprehensive listing of submissions to the Inquiry and identifies individuals and organisations that have assisted the Inquiry in its investigations.

Some of the discussion in the Interim Reports has not been carried into the Final Report. In particular, consideration of the quality of the catchment, which has now been addressed by the Parliament, has not been discussed in any detail in the Final Report. The Final Report is intended to be authoritative in relation to all matters.

Public submissions

The Inquiry has been conducted primarily by interview and discussion with a great many people. A complete list of those interviewed and consulted is included in the appendices.

The Inquiry has received over 200 submissions in response to the initial Terms of Reference and the ongoing events. I have also met and spoken with over 130 people since the Inquiry commenced. Concerns raised in these submissions focused on the following matters:

- health impacts strong representations requesting consistent and clear health advice on possible impacts of *Cryptospoidium* and *Giardia* on immuno-compromised individuals. Various submissions were received from individuals identifying possible illness associated with the contamination events. Representations also expressed concern about the quality of information on the health impacts of *Cryptospoidium* and *Giardia* and the levels of chlorine in drinking water;
- management of the incident concerns were expressed about the timeliness, quality and the consistency of information provided by Sydney Water. Specific concerns were raised about the adequacy of communication to ethnic communities. Inconsistencies in the communications of NSW Health and Sydney Water during the boil alert were also identified;
- management of the assets and resourcing levels concerns were expressed about impacts of corporatisation on staff numbers, water pricing, water quality monitoring and the maintenance of the distribution system, and accountability to the Government and consumers;
- water quality submissions identified various possible sources of contamination in the catchment and expressed concerns about the adequacy of the current treatment methods. Concern was expressed about the impact of

boil water alerts on Sydney's international reputation and the need to prevent ongoing contamination;
- water filtration and monitoring concerns were expressed about the lack of treatment standards for *Cryptospoidium* and *Giardia* and delays in detecting the parasites in water;
- catchment protection submissions identified possible sources of contamination in the catchment and the adequacy of resourcing for catchment protection works. Specific concerns were raised about the adequacy of planning and the range of potential threats to water quality currently permissible within the catchment;
- compensation submissions expressed concerns about the level and distribution of rebate payments and the impacts of the contamination events on low income earners; and
- future directions submissions sought reassurance that action would be taken by the Government to prevent a recurrence of the contamination events and identified various policy, regulatory and operational measures.

A list of submissions received and a summary of the issues raised are included in the appendices.

Reporting the Events

The Inquiry has proved complex and difficult. In part it has been carried out at the same time as the contamination incidents and this had a number of consequences. It placed considerable burdens on the staff of Sydney Water who were required to manage the events and simultaneously respond to requests from the Inquiry. My thanks go to the numerous staff involved. I appreciate the professionalism they have shown and the contributions they have made to ensure the future quality of Sydney's drinking water.

The continuation of the events over a number of weeks while the Inquiry was under way also provided Sydney Water with the opportunity to access the scientific and engineering expertise from Australia and overseas which had been gathered for the Inquiry. I am not aware of any other public health alert which has had the benefit of adapting the public health response throughout the management of the incident, rather than using the wisdom of hindsight to modify future practices.

The Inquiry process

The Inquiry has been assisted by a wide range of operational, management and scientific experts. Mr David Harley and Mr Bernie McKay have acted as advisers to the Inquiry. Mr Harley is Chairman of the NSW Environment Protection Authority and a former Chair of the Sydney Water Board. Mr McKay is a former head of the South Australian, New South Wales and Commonwealth Departments of Health and a former Chairman of the National Health and Medical Research Council. He has worked full time with the Inquiry and supervised the science and medical research aspects.

I have received detailed submissions and other material from Sydney Water Corporation, NSW Health, the Environment Protection Authority, the Department of Land and Water Conservation, and Australian Water Services Pty Ltd (AWS). My thanks go to all the staff involved in the preparation of these submissions and the support they provided to the Inquiry.

In particular, I appreciate the efforts of Ms Angela Tsoukatos and her staff at Sydney Water who provided the Inquiry with timely and professional assistance over the past four months, in addition to managing ongoing operational responsibilities. I would also like to acknowledge the technical assistance provided by Sydney Water employees and advisers and that of AWS and Australian Water Technologies (AWT) in co-operating with the Inquiry to identify causes of the contamination and provide advice on future management issues.

Sydney Water, AWT and AWS were all legally represented at various stages of the Inquiry, as were individuals from those organisations. A list of the legal representatives is included in the appendices.

The Inquiry has consulted a number of Australian and international scientific experts in microbiology, parasitology, filtration, water treatment, public health, epidemiology and engineering. A list of these advisers is included in the appendices.

Throughout the Inquiry I have been assisted by Dr Colin Fricker who is the Microbiology and Laboratory Manager at Thames Water Utilities in the United Kingdom. He provided expertise at a high level without which the Inquiry could not have determined many of the scientific problems. I appreciate the dedication and personal sacrifices he made to provide me with this assistance.

In an effort to co-ordinate the available expertise and bring the resources of Sydney Water and AWS to bear on the problem, a Joint Action Group (JAG) was formed. It consisted of Sydney Water and AWS staff, and a number of international experts, listed in the appendices. They advised the Inquiry on specific topics and conducted a number of investigations on its behalf. A final JAG report has been prepared and I propose that it be made available to interested parties. I appreciate the efforts of the Group during the Inquiry.

I also had the opportunity to attend an international conference on Cryptospoidium in water where Dr John Langford arranged for me to meet with world experts in the area. I am grateful for the assistance Dr Langford provided throughout the Inquiry.

I have also inspected the Prospect plant, the AWT Laboratory and both the Inner and Outer Catchments.

Inquiry staff

At the outset of the Inquiry no-one imagined the complexities of the investigation. I have been most fortunate in having the assistance of a small number of extremely dedicated staff. Many policy matters required detailed consideration and I particularly

appreciate the depth of knowledge of these issues within the team. Long days and most weekends were the norm and I am immensely grateful for the enthusiastic efforts and the contribution of the entire staff.

The members of the staff were:

Marion Bennett Principal Policy Officer;

Janet Dawson Principal Policy Officer;

James Grainger Principal Policy Officer;

David Norris Legal Officer;

Gavin Morrison Research Officer;

Alexander Weilsmann Executive Officer;

Barbara Higham Office Manager;

Leonie Maher Document Manager; and

Melanie O'Neill Administrative Assistant.

Ms Robyn Kruk headed the Secretariat directing the research and information gathering process. I was fortunate in having such a dedicated and talented person in this role.

Chapter 2: Recommendations and actions

This chapter outlines the recommendations made in the five reports produced by the Inquiry. The relevant Report is identified so that further background information may be obtained.

When additional recommendations have been made, or when I have modified an earlier recommendation, this is identified.

In addition, this chapter identifies the action which has been taken by the Government to implement the recommendations arising from earlier reports.

Management of the incident by Sydney Water and NSW Health

These issues are considered in the Second Interim Report.

Recommendations

1. A comprehensive Incident Management Plan must be developed.

2. Sydney Water and NSW Health must refine the relevant procedures and undertake staff training to prepare for the future management of contamination incidents.

Action taken

Sydney Water has commissioned a review of its incident management plans. The review identified many examples of excellence both in incident preparedness and response, and the commitment and dedication of staff during the recent events. The review, however, found that strategic and corporate crisis response was inadequate.

The review developed recommendations to address the weaknesses. These recommendations have been endorsed by Sydney Water's Board of Directors. Sydney Water is currently developing an implementation plan and comprehensive incident management training.

Sydney Water and NSW Health have revised the MoU relating to incident management. It now includes requirements to develop joint incident management plans and conduct joint training exercises. It also increases Sydney Water's obligations to provide information to NSW Health in the event of an incident.

Public health alerts

These issues are considered in the Second Interim Report.

Recommendations

3. NSW Health must have clear authority to make public health alerts in relation to drinking water incidents.

4. NSW Health must develop the expertise necessary to make public health decisions about the impact of a potential contaminant in the water supply system.

5. The MoU between NSW Health and Sydney Water should be reviewed, particularly in relation to operational and communication difficulties experienced during the contamination event.

6. The MoU should be supported by an Interim Health Protocol which identifies appropriate triggers to institute action in response to positive findings of *Cryptosporidium* and *Giardia*, and the circumstances leading to boil water alerts and their subsequent lifting.

7. The Interim Protocol should recognise that the decision to issue a health alert will not be based on a single test result alone, but on factors including the following:

- presence of faecal coliforms;
- evidence of suspected source of contamination;
- malfunctioning chlorinator/treatment failure;

- evidence of human disease;
- the persistence and reported occurrence of parasites;
- the size and demographics of the population potentially affected;
- raw and treated water turbidity; and
- other relevant factors.

8. The Interim Protocol should remain in place until the NHMRC finalises the development of national guidelines.

9. There should be one spokesperson with appropriate authority to make statements on public health alerts.

Action taken

The Government requested the NHMRC to conduct an accelerated revision of its 1996 guidelines, focusing on *Cryptosporidium* and *Giardia*. A new draft guideline is expected to be released for public comment before the end of 1998.

NSW Health issued an Interim Health Protocol following detection of *Cryptosporidium* oocysts or *Giardia* cysts in drinking water in September 1998. The protocol makes it clear that the Chief Health Officer is responsible for the issue of boil water alerts and outlines the role of the expert panel in advising the Chief Health Officer. The Interim Protocol responds appropriately to all the issues raised in my earlier report.

The Government has amended the *Public Health Act 1991* to give the Chief Health Officer the exclusive statutory responsibilities for issuing boil water alerts, in a package of new regulatory powers for NSW Health.

Community education

These issues are considered in various reports.

Recommendations

10. The community must have the opportunity to develop an informed understanding of water quality issues and the risks to public health, through the development of a public education program. This should address the following:

- *Cryptosporidium* and *Giardia* are commonly found in the environment, and humans are exposed to these organisms in the course of their everyday activities;

  METCALFE: "On receipt of those fact sheets it was the assessment of me and others in the communications team that they were too detailed and too complex in terms of a simple message for the media, so therefore should not be issued with the media release."

- Metcalfe says that he faxed the draft media release to Armistead before 3:30pm. However, Armistead states that she did not receive it until 5:00pm, and had called at 3:00pm and again at 4:00pm to find out what was happening with the release.

  At 5:15pm, Armistead recommended changes to the release to Metcalfe via telephone. Metcalfe says that she requested changes, including the removal of any statement of NSW Health's support for Sydney Water actions. NSW Health requested the completed release be faxed back to NSW Health.

  At 6:00pm, Armistead contacted Metcalfe to ask for a copy of the completed release. Metcalfe advised that the release had been sent out at about 5:45pm. At 6:15pm, Health received a copy of the release from Sydney Water. The media release is in the appendices.

  There was an unacceptable delay in issuing the media release. I cannot resolve who caused the delay. Obviously the debate about the need for a media conference contributed to the delay and was only resolved by Reid contacting Pollett. It is plain that the relationship between Sydney Water and NSW Health was not functioning effectively at this point. The delay in issuing the media release could have had serious health consequences. It also caused NSW Health to form an adverse view of the promptness of Sydney Water's media section, a view which played a large part in NSW Health's decision to issue Sydney Water's media statement on the Wednesday night.

  Tuesday 28 July

  Results received on Tuesday 28 July indicated some further low positive results from sites tested on the previous day, including Macquarie Street (2C/1G), College Street (4C/6G) and Crown Street reservoir (0C/14G). Other eastern suburbs sites tested negative. However, a site at Rhodes also tested positive (0C/4G).

  Sydney Water completed a letterbox drop to all customers in the eastern CBD area, advising them of the local boil water alert.

  Visual inspections and testing of the suction well site, which is the source of the Rhodes supply, were conducted. The Rhodes system was flushed as a precautionary measure. It was also decided to drain the Crown Street reservoir and take further samples throughout the system up to Potts Hill.

  NSW Health was provided with the test results and prepared a statement, which is in the appendices, for the Sydney Morning Herald explaining why a boil water alert had been issued and the link between *Cryptosporidium* in drinking water and public health. The statement said:

  A Statement from NSW Health for Sydney Morning Herald 28 July 1998

  "Over the past year NSW Health has conducted intense active surveillance for evidence of disease which could be attributed to *Cryptosporidium* in drinking water. So far no disease has been detected.

  During the weekend NSW Health carefully monitored reports of water testing from Sydney Water.

  On Monday new evidence came to light showing the source of the organisms was possibly due to a problem with the pipes that allowed contaminated water to be sucked in.

  It was at that point it was decided a warning should be issued as a precaution.

No relationship has been established between finding *Cryptosporidium* in drinking water at any level (in Australia or elsewhere) and effects on human health.

That means a high level versus a low level does not necessarily indicate an increased risk.

This is also supported by a large survey of treated North American water supplies that showed that despite the presence of *Cryptosporidium* there was no evidence of human disease.

The lack of association between *Cryptosporidium* in drinking water and human illness may be because the organisms are killed during water treatment processes".

The Sydney Morning Herald quoted this statement in part, including the following.

Catchment protection minimising sources of contamination and establishing a catchment authority

These issues are considered in the Third Interim Report.

A regional plan for the catchment that gives priority to water quality

Recommendations

17. Water quality should be the primary consideration in decision making affecting the catchment. The Government must provide clear direction and adequately resource the efforts to bring together the relevant state, local government and community interests.

18. The Healthy Rivers Commission should be directed to undertake an expedited inquiry covering the entire Hawkesbury Nepean catchment in order to identify water quality objectives and broad strategic goals for the hydrological catchment.

19. The Healthy Rivers Commission should formulate its recommendations in consultation with the community, and with the Government agencies and councils which will be responsible for implementing the objectives and strategies.

20. The objectives and strategies should be given statutory force by inclusion in a Regional Environmental Plan (REP) for the catchment. This will ensure they are applied when consent authorities review existing development activities and that they will guide future development decisions.

21. A State Environmental Planning Policy (SEPP) should be developed immediately as an interim measure for the hydrological catchment. This should provide the parameters for acceptable development based on current information on water quality.

22. The SEPP should identify the concurrence role of the catchment authority and development consent arrangements, including development permissible with the consent of councils, state significant developments for the consent of the Minister, and prohibited uses.

23. A Regional Environmental Plan (REP) should be developed for the Warragamba and Upper Nepean hydrological catchment, covering both the Inner and Outer Catchment areas.

24. The REP should be a prescriptive instrument that:

i. Incorporates the broad catchment wide strategies developed through the Healthy Rivers Commission's inquiry process and endorsed by the Government.

ii. Controls the actions and decisions of state agencies and local government authorities in the catchment.

iii. Incorporates water quality objectives that are developed through the Healthy Rivers Commission and will be binding on agencies.

iv. Specifies that consent authorities must not approve a development application unless it has neutral or positive impacts on water quality in the catchment.

v. Specifies that all new Local Environmental Plans (LEPs) must be consistent with the REP.

vi. Specifies that councils will be required to review existing LEPs within a prescribed time frame to ensure consistency with the REP.

vii. Requires councils to develop amelioration plans, in consultation with the Government, within a prescribed time frame to develop strategies to address existing developments which pose significant threats to drinking water quality.

viii. Incorporates the Special Areas Strategic Plan of Management jointly developed by Sydney Water and the National Parks and Wildlife Service.

ix. Is oversighted by the catchment authority.

Establish a catchment authority

Recommendations

25. A catchment authority should be established that is responsible for providing water quality of a prescribed standard and controlling relevant infrastructure.

26. The catchment authority should have the following functions and powers:

- be accountable to a Minister and have a statutorily defined set of objectives to protect drinking water quality and manage the health of the catchment;
- oversight the implementation of the proposed REP;
- exercise a concurrence power over developments when a council is the consent authority;
- be consulted on proposed developments when the Minister is the consent authority;
- independently report to Parliament on a regular basis on its assessment of the health of the catchment;
- undertake research on the health of the catchment;
- be responsible for the Inner Catchment (managed by the National Parks and Wildlife Service), with enhanced regulatory and enforcement powers in both the Inner and Outer catchments;
- own and maintain the relevant infrastructure;
- use Catchment Management Committees and other mechanisms to ensure community participation in its activities;
- undertake an educative role with the community;
- have its performance audited by the restructured Licence Regulator; and
- have power to ensure compliance with existing laws and regulations.

Protection of the Inner Catchment

Recommendations

27. The Government should urgently release and implement the Special Areas Strategic Plan of Management proposed by Sydney Water and the National Parks and Wildlife Service.

28. The Plans should be incorporated in, and enforced through, the proposed REP as part of the whole of catchment approach.

29. The National Parks and Wildlife Service should manage the Special Areas for both water quality and broader ecological considerations.

30. The National Parks and Wildlife Service should be adequately resourced to manage the Special Areas.

31. The Special Areas should be declared as national parks/nature reserves.

Assessment of the state of the catchment

Recommendations

32. The catchment authority should conduct a full assessment of the present state of the catchment. This must incorporate both ecological information and an evaluation of the pressures posed by development in the catchment. Research on catchment protection measures should be a priority.

33. The catchment authority should be responsible for conducting water quality monitoring in the catchment under the supervision of the EPA.

34. The catchment authority should report to Parliament on its assessment of the state of the catchment and the achievement of water quality objectives in the REP. This should be in the form of a State of the Catchment report.

Regulating the catchment

Recommendations

35. The EPA should be the primary environmental regulator in the catchment. Its role should be strengthened as any diminution of its powers has the potential to undermine an important part of the regulatory framework.

36. The EPA should be given a strong mandate and resources to address both point source and diffuse pollution sources within the catchment.

37. The EPA should be the agency responsible for providing primary assistance to the Healthy Rivers Commission to facilitate development of clear water quality objectives within a prescribed timeframe for incorporation within the proposed REP.

38. The EPA must have the power to co-ordinate regulation of water quality within the catchment across state and local government agencies.

39. Consideration should be given to unifying the environmental health responsibilities of NSW Health and the EPA to ensure better co-ordination based on agreed water quality data.

40. The EPA's existing powers should be utilised to complement the proposed REP, where appropriate, to influence decision-makers on existing practices or operations. For example, the proposed Protection of the Environment Policies and the use of section 12 of the *Protection of the Environment Administration Act 1991* to direct public authorities on any environmental matters.

Improvement of regulatory and enforcement powers in the inner catchment

Recommendations

41. The catchment authority should be given the power to draw upon the enforcement powers of the regulatory agencies, such as the Department of Land and Water Conservation, EPA and National Parks and Wildlife Service and to allow officers of those agencies to enforce the authority's regulations.

42. The catchment authority should be given the powers to issue fines and compel people to provide their name and address in the event of illegal access

to the Special Areas.

Community involvement and the role of catchment committees

Recommendations

43. The Government should continue to support the Catchment Management Committees in their work to improve current agricultural and other land use practices impacting on the catchment.

44. The Government should review the existing membership of the Committees to ensure that a balance is achieved between representatives of competing interests and to ensure that they are adequately resourced.

45. The catchment authority should consider establishing a forum with representatives of the Hawkesbury-Nepean Catchment Management Trust and the Catchment Management Committees to provide advice on specific issues as well as its general work program.

46. The proposed review of the Hawkesbury-Nepean Catchment Management Trust take should into account the new responsibilities of the catchment authority.

Water Auditor

Recommendations

47. There must be an independent audit body which has the ability to critically review and report on the performance of all parties in meeting the endorsed water quality objectives and the catchmentwide strategies incorporated in the proposed REP. The Licence Regulator should be restructured, provided with the necessary resources to undertake this role, and given a clear set of operating objectives.

48. The restructured Licence Regulator should undertake independent audits of the proposed catchment authority and the activities of the primary regulators, namely the EPA and the Department of Land and Water Conservation, with respect to their catchment activities and their performance in implementing the proposed REP.

Provision of sufficient resources for catchment protection

Recommendation

49. The Government should initiate an inquiry by the Independent Pricing and Regulatory Tribunal to ensure that there is adequate funding provided to the catchment authority to enable it to meet its primary objective of ensuring water quality.

Action taken

A Bill establishing the Sydney Catchment Authority (SCA) has passed through the Parliament.

The Authority will be responsible for management of Sydney's drinking water catchments.

The role of the Authority is to manage and protect the Inner and Outer Catchment areas and associated infrastructure, to supply bulk water (to Sydney Water and other water supply authorities), and to regulate certain activities within or affecting the catchment areas. The Authority will be responsible for ensuring the catchment areas are managed to optimise water quality and for ensuring that water supplied by the Authority complies with appropriate standards.

The Authority will assume Sydney Water's responsibilities in the catchment, including ownership of land. The Bill provides for the Authority to exercise a concurrence power over development in both the Inner and Outer Catchments, and provides for concurrence and other roles in connection with the grant of licences under other legislation, such as the pollution control legislation, which affects the catchment areas. The Authority will also be able to exercise an inspection or enforcement role under other legislation in relation to activities carried out in the catchment area.

The legislation makes the Authority subject to a similar regulatory framework to Sydney Water involving an Operating Licence, including auditing by the Licence Regulator.

The *Sydney Water Catchment Management Bill* requires the making of an REP which:

- sets water quality objectives for the land to which the plan applies;
- requires development consent for only those developments with a neutral or beneficial effect on the quality of water; and
- requires the development of action plans to rectify any development that does not have a neutral or beneficial effect.

A State Environmental Planning Policy is currently in preparation. It is proposed that the concurrence role will initially be exercised by the Director-General, Department of Urban Affairs and Planning, prior to the establishment of the Sydney Catchment Authority.

The Healthy Rivers Commission has been directed to commence an inquiry identifying water quality objectives and broad strategic goals for the hydrological catchment.

The science

This issue is considered in my Second Interim Report and in the Final Report.

Recommendations

50. A suitably qualified independent laboratory should be established to provide accurate data for regulatory authorities. The laboratory must be adequately resourced.

51. AWT should continue to perform these tasks until the new laboratory is available, with the assistance of appropriate external expertise during the interim period.

52. Laboratories providing parasite analysis should be accredited by National Association of Testing Authorities (NATA), utilising an approach similar to that implemented by the US EPA.

53. AWT should continue to perform analytical work for Sydney Water in the longer term, to assist it in its management responsibilities, subject to appropriate training of staff and quality control.

Action taken

The Cabinet Office Task Force has commissioned a review.

Health impacts

This issue is considered in my Third and Final Reports.

Recommendations

54. The community should be informed about the potential health impacts of *Cryptosporidium* and *Giardia* by a public education campaign explaining the agreed scientific facts and the gaps that exist.

55. The Interim Health Protocol should be amended to remove reference to viability and specific levels of *Cryptosporidium* and *Giardia*. This is because of the scientific uncertainties.

56. NSW Health should issue a further advice to the immuno-compromised community making clear the potential risks from *Cryptosporidium* from water and other sources. The advice must state that all tap water consumed by immuno-compromised persons should be brought to the boil before use.

Appropriate quality control also needs to be introduced for bottled water and home filters. This advice is consistent with international best practice.

57. The general public education campaign should be accompanied by a special campaign targeting the immuno-compromised community to convey clear and consistent messages to at risk groups about the need to boil water.

58. The public campaign should be accompanied by an information and education program for medical practitioners, focusing on advice that should be given to the immuno-compromised. The campaign should be developed in consultation with peak bodies representing the immuno-compromised community.

59. Additional epidemiological studies should be undertaken to assist our understanding of the relationship between *Cryptosporidium* and *Giardia* in drinking water and public health.

60. NSW Health should be responsible for publishing the results of studies commissioned by the Inquiry to clarify the role of protective immunity, if any, in the recent contamination events.

Action taken

NSW Health has been given responsibility for implementing each of these recommendations.

Regulation of Sydney Water and the Sydney Catchment Authority

This issue is considered in the Final Report

Operating Licence

Recommendations

61. The current Operating Licence should be replaced with a licence which clearly outlines for both Sydney Water and the Sydney Catchment Authority:

● the authorities' obligations in terms of customer and operating/health and environmental outcomes;

● the actions to be taken and sanctions applied in the event that obligations are not met; and

● audit and review provisions clearly outlining the role of the Water Auditor and the processes, timeframes and other triggers for review, including the introduction of revised standards and future contamination events.

62. The revised Operating Licences should be developed through a consultative and transparent process which is at arm's length from Sydney Water and the Sydney Catchment Authority.

63. The initial consultation process should be conducted by the Independent Pricing and Regulatory Tribunal (IPART). IPART should be requested to make recommendations to Government on the terms of the Authority's initial licence and Sydney Water's next licence to apply from 1 July 1999. Subsequent reviews should involve the restructured Licence Regulator.

64. There should be opportunities to review operating standards in line with changing community expectations and an increased understanding of costs and benefits.

65. The development of the Sydney Catchment Authority's Operating Licence and the review of Sydney Water's licence should be conducted concurrently.

Licence regulator

Recommendations

66. The Licence Regulator's role and membership should be modified to enable it to undertake a stronger and better defined role in the management of Sydney's water. It should be renamed so that its title more effectively communicates its enhanced role perhaps the Water Auditor.

67. The Water Auditor should be required to investigate and audit any matter concerning the performance of both authorities against their Operating Licences on an annual basis. In addition it may obtain the Minister's agreement to conduct on-the-spot audits.

68. The Water Auditor should be able to audit the operations of parts of Sydney Water and the Sydney Catchment Authority which are owned and/or operated by organisations external to the authorities, but form part of the overall treatment and distribution system. This includes the water filtration plants.

69. The structure and resourcing of the Water Auditor should reflect its role and responsibilities. It should comprise a full time Executive Director and appropriate full time staff. The Water Auditor's Board should comprise the Executive Director together with a non executive chair and directors who have a proven track record of balancing the interests of all stakeholders as well as experience in appropriate areas such as health, environment, consumer affairs, business, finance, water and engineering.

70. The Water Auditor should have the power to report to Parliament.

71. The Government should review the relationship between the Water Auditor and the shareholding, Operating Licence and regulatory Ministers to ensure that conflicts of interests are removed.

Memoranda of Understanding

Recommendation

72. The Operating Licence should be amended to require that MoUs include targets, timelines and review provisions, and specifically require the Water Auditor to audit their contents. The existing MoUs between Sydney Water and its regulators should be reviewed to reflect these new requirements as a matter of urgency. The same scrutiny should be extended to the proposed MoUs between the Sydney Catchment Authority and its regulators and other agencies.

Complaint mechanisms

Recommendation

73. Sydney Water should be required to join or establish an independent industry based dispute resolution scheme.

A mandatory water quality level for *Cryptosporidium* and *Giardia*

This issue is considered in the Final Report.

Recommendations

74. Public health decisions should not be made on the basis of detecting only the presence or absence of *Cryptosporidium* and *Giardia* in drinking water. Informed public health decisions need to take into account a range of other factors. These include factors affecting infectivity, such as viability, strain, and source.

75. Consideration should be given, but not restricted to, the following four parameters in making public health decisions:

- number of cysts and oocysts;
- volume of water in which oo/cysts are detected;
- frequency of testing of samples; and
- detection methodology and recovery efficiency of the testing procedure.

76. The goal of all water providers should be to provide supplies clear of viable *Cryptosporidium* and *Giardia*. This should ultimately be reflected in contractual and licensing obligations.

77. It would be inappropriate, having regard to the present level of scientific knowledge, to provide mandatory health related standards.

78. Water suppliers should be required to operate their treatment plants at an optimum level and have in place comprehensive monitoring programs for raw water quality and treatment plant performance.

79. Consideration should be given to identifying specific levels of *Cryptosporidium* and *Giardia* for drinking water as triggers for operational decisions such as changing the management of the plant or undertaking additional works such as treatment augmentation, catchment protection or maintenance works. The setting of these levels would provide a performance standard against which the performance of the plant can be measured.

80. Consideration should be given to the consequences of applying an operational water quality standard, including cost/benefit analysis.

81. The Government should review the position with a view to imposing an operational water quality standard at the end of 1999. This review should be informed by the work of the NHMRC.

82. Protocols should be developed between NSW Health, Department of Land and Water Conservation, EPA and country water suppliers to ensure effective public health outcomes.

Monitoring

This issue is considered in the Final Report

Recommendations

83. Monitoring programs should do the following:

● assess the likely occurrence of contamination in the raw water;

● assess the performance of water treatment in removing the specific contaminant;

● include a database of monitoring results taken from raw water so background levels of contamination can be understood. This allows the setting of base levels which, if exceeded, trigger an "event" which can initiate special operational and public health measures such as increased chlorination or boil water alerts; and

● have clear linkages to public health and operational decisions.

84. The revised monitoring regime jointly developed by Sydney Water, NSW Health and the EPA should be implemented.

85. A panel should be established to review the ongoing effectiveness of the monitoring program. This panel should identify further research needs. It should include representatives from Sydney Water, NSW Health, EPA, AWS and the Sydney Catchment Authority.

The efficiency of the filtration plants

This is considered in the Final Report.

Recommendations

86. The prototype plant should be maintained and utilised for a thorough testing regime.

87. The research identified in Chapter 16 should be conducted with appropriate priorities and have the necessary funding.

Future improvements

These issues are considered in the Final Report.

Recommendations

88. Augmentation of the filtration plant is not justified at this stage. Effective catchment management, improved operation of the water storages and improvements to the operations of the Prospect plant should be implemented. In the event of any future contamination events, the need for augmentation should be reviewed having regard to the further knowledge which has now become available.

89. The following improvements to the drinking water system should be implemented as a matter of priority:

(i) improvements in catchment management. These are detailed in my Third Interim Report and include enhancing the capacities of sewage treatment plants, acceleration of the program to sewer urbanised areas close to Warragamba, measures to address pollution from intensive agricultural industries; measures to minimise animal faeces entering water courses especially in the Inner Catchment, and investigation of the biosolid application practices in the catchment;

(ii) a research program which examines catchment protection measures should be accelerated and the Sydney Catchment Authority should decide, as a matter of priority, on a program of remedial and preventative works;

(iii) development and maintenance of an information database including gauging information systems, catchment modelling, river modelling and lake modelling;

(iv) improvements in management of the storages, including appropriate research to guide the optimum strategy for lake management;

(v) use of Prospect Reservoir as an alternative storage area when the primary water storage is discovered to be contaminated. Before this can be done, an environmental risk analysis and review must be undertaken in consultation with the EPA. The practice of pumping treated backwash water into the reservoir should cease. Prospect's backwash water should be further treated and returned to the head of the works;

(vi) consideration should be given to covering the Upper Canal in those parts where it is most exposed to contamination risks. Until this is completed, I recommend that the use of Upper Canal water be carefully monitored and managed appropriately during heavy rain events;

(vii) improvements to optimise the performance of the Prospect plant. Measures which could be undertaken to ensure that the plant maximises its potential to produce clean water include:

- ensuring that a turbidity standard of 0.1 NTU, as is currently achieved, is maintained;
- optimisation of the coagulant dosing;
- introducing on-line particle counters to more closely monitor performance; and
- shortening filter runs.

(viii) Sydney Water should treat the backwash water with deep bed filtration to provide an additional barrier and reduce contaminant levels to some extent, particularly during heavy contamination events;

(ix) improvements to the distribution system to prevent contaminants building up in the pipes and hydrants; and

(x) a comprehensive improvement package, including future research and planning by Sydney Water, AWS and the Sydney Catchment Authority, and introducing quality assurance procedures as a framework for guiding water quality protection.

The contract for the Prospect Water Filtration Plant

This issue is considered in my Fourth Report.

Recommendation

90. That the Government consult with the parties with a view to releasing the details of the contract for the Prospect plant, excluding only matters which would damage the ongoing commercial interests of either party.

Research agenda

These issues are considered in the Final Report.

Recommendation

91. Research should be undertaken in relation to the areas mentioned below. They are discussed in Chapter 16 of the report. Priorities should be identified, having regard to the available funding:

- understanding the organisms and the testing methods including quality assurance;
- the issue of viability of pathogens;
- specific detection of *C. parvum*;
- genotyping of *Cryptosporidium*;
- catchment and dam management;
- treatment plant processes and efficiency;
- the health impacts of *Cryptosporidium* and *Giardia* ; and
- the protection of water quality within the distribution system.

Chapter 3: Description of the Events

Sydney experienced three events in July, August and September 1998 when high and occasionally very high levels of *Cryptosporidium* and *Giardia* were recorded in the drinking water supply, resulting in boil water alerts issued for parts or all of the city. These events are referred to as the First, Second and Third Events and occurred for the following periods:

- First event: Tuesday 21 July to Tuesday 4 August 1998;
- Second Event: Monday 24 August to Saturday 5 September 1998; and
- Third Event: Saturday 5 September to Saturday 19 September 1998.

This chapter provides a brief description of the contamination events focusing on where positive readings of *Cryptosporidium* and *Giardia* were taken and when boil water alerts were in place. Sydney Water and NSW Health issued boil water alerts during the First Event with NSW Health assuming sole responsibility for issuing boil water alerts during the Second and Third Events.

As required by my terms of reference, I have reported on the adequacy of the management response to the First Event in Chapter 4 (Management of the Events). I have also commented on the management response for the Second and Third Events.

Australian Water Technologies (AWT) has provided me with a full set of the sampling results for *Cryptosporidium* and *Giardia* taken throughout the three events. These are provided in the appendices.

There has been considerable debate about the quality of the laboratory work undertaken by AWT throughout the events. Although it has been agreed that AWT correctly identified *Cryptosporidium* and *Giardia*, the actual numbers remain in dispute, as discussed in Chapter 8 (*Cryptosporidium* and *Giardia* A picture of uncertainty).

Description of Sydney's water system

Sydney Water supplies approximately 1,500 million litres of water each day to more than 3.8 million people in the Sydney, Blue Mountains and Illawarra regions. A network of nine major dams plus several minor storage reservoirs is used to collect and store water which, in turn, is delivered to a network of over 20,000 km of water mains, 165 pumping stations and 261 service reservoirs.

The water supply is drawn from catchments on four main river systems the Upper Nepean, the Warragamba, the Shoalhaven and the Woronora with minor supplies drawn from the Hawkesbury River, and tributaries of the Grose, Fish and Duckmaloi Rivers.

Since late 1996 all of Sydney's water supply has been filtered. Eleven water treatment plants are used to filter drinking water supplied to Sydney, Illawarra and the Blue Mountains. Seven of these facilities are owned and operated by Sydney Water. These are located at Orchard Hills, Cascade, North Richmond, Nepean, Warragamba, Linden and Greaves Creek.

The remaining four privately-owned and operated plants at Prospect, Macarthur, Illawarra and Woronora provide filtered water under contract to Sydney Water. These four plants provide more than 90% of Sydney's drinking water. Up to 80% is supplied through the Prospect plant alone. The water is distributed from Prospect to Pipe Head by tunnels and mains, with some areas supplied directly from these mains. From Pipe Head, water for the inner city, suburbs south of Sydney Harbour and inner western suburbs is carried by tunnel and mains to two large service reservoirs at Potts Hill and then by two tunnels (the Pressure Tunnel and City Tunnel) which terminate at Waterloo and Dowling Street pumping stations. Two pumping stations one at Prospect and one at West Ryde supply water for the northern suburbs and Warringah. The water for Ryde is supplied from Pipe Head.

A map of the Warragamba and Upper-Nepean Catchments and a diagram of the distribution system from the Prospect plant are in the appendices. A map showing the locations of the major water filtration plants is also included.

Overview

Cryptosporidium and *Giardia* were detected in the raw and treated water at the following water treatment plants at different times during the three events: Warragamba, Nepean, North Richmond, Orchard Hills, Woronora, Macarthur, Illawarra and Prospect.

The levels of water contamination at Prospect were of particular concern, given that it supplies most of Sydney's drinking water. Once it was agreed that the Prospect was the likely source of contamination, Sydney Water rightly concentrated sampling at the plant rather than continuing extensive sampling at consumers' taps. The expert panel agreed with this approach.

As a result, the majority of samples taken throughout the events were in the raw and treated water at the Prospect plant. This information has been plotted on graphs to illustrate when increases in parasite numbers occurred in the raw and treated water at Prospect, and the magnitude of these increases. The number of *Cryptosporidium* leaving the distribution system is also presented using readings taken at the same time from the extremities of the Potts Hill system, which is supplied from Prospect. These measurements were taken from both hydrants and consumers' taps.

The levels of *Cryptosporidium* used for the graphs have been adjusted to a standardised sample volume of 100 litres. The sample volumes for raw water tested during the events were 20 litres or less. There were also variations in the sample volumes for treated water, which have also been adjusted.

The levels of *Giardia* that were detected in Sydney's water have not been included in these graphs. As discussed elsewhere, waterborne *Cryptosporidium* is accepted to pose a greater threat than *Giardia*, which is more likely to be killed by the chlorination which is undertaken at all of Sydney's treatment plants.

AWT has made a detailed submission on the relationship between the numbers of *Cryptosporidium* in the raw water, the numbers leaving the Prospect plant and the numbers found in the distribution system. While the data appears to show distinct correlations between all three stages, a number of assumptions have been made in drawing a conclusion that the only significant source of contamination was the raw water. Chapter 6 discusses the causes of the three contamination events.

First Event: Tuesday 21 July to Tuesday 4 August 1998

This section outlines when and where *Cryptosporidium* and *Giardia* were reported during the First Event and when boil water alerts were issued in response. The information focuses on when the sample was reported rather than when samples were taken, which is provided in the table of all positive results in the appendices. Generally, samples of 100 litres were used but there was some variation as indicated.

On 21 July a low level of *Giardia* [3 *Giardia* cysts per 100 litres (3G)] was confirmed at the Prospect distribution chamber from a sample taken on 15 July. On the same day low levels of both *Giardia* (2G) and *Cryptosporidium* [2 oocysts per 100 litres (2C)] were confirmed at Potts Hill reservoir. These were detected as part of routine water sampling.

Under the existing arrangements Sydney Water informed NSW Health of the event. The levels did not raise health concerns.

Further tests of the positive sites and additional tests of various other sites around Prospect and Potts Hill were commissioned that day. Test results received on 22 July showed all clear, except one sample from Sydney Hospital (0C/1G).

On Thursday 23 July, results from a retesting of the Sydney Hospital site on 22 July showed a higher positive result (43C/19G). Surrounding sites tested showed all-clear.

Test results received on Friday 24 July from a sample taken the previous night showed the all clear for all areas tested except an outlet at Sydney Hospital (1C/0G) and at the Art Gallery (16C/16G), which are both fed from the same main. At this stage, it was considered that a localised contamination problem existed.

On Saturday 25 July, further tests from samples collected the previous day showed positive levels at the Art Gallery (10C/106G), Macquarie Street (15C/161G) and Crown Street pumping station (10C/5G). A test of a smaller sample collected at the corner of Liverpool and Crown Streets showed 4C and 13 G per 1.5 litres. At this stage, tests were ordered throughout a wider part of the Sydney distribution system. After flushing of most of the affected area, tests of the first flush water from College Street showed high readings (104C/461G).

On Sunday 26 July, test results from the previous day's samples showed extremely high levels from Macquarie Street (376C/3952G), College Street (170C/332G) and the Art Gallery (200C/963G) and lower levels from Crown Street reservoir (6C/20G) and the corner of Liverpool and Crown Streets (1C/16G). Test results for Prospect plant, Potts Hill, Thornleigh and West Ryde were negative, however the City Tunnel at Greenacre showed a low positive result (0C/8G). This was the first positive reading received outside the eastern CBD (other than the initial low readings from Prospect distribution chamber and Potts Hill).

If these elevated readings were found in a significant section of a water supply system they could justify a health alert.

On Monday 27 July a public notice was issued warning persons in the affected area of the eastern CBD not to drink unboiled water. Results from Sunday tests were received later that day showing the all clear. Results received on Tuesday 28 July indicated some further low positive results from sites tested on the previous day, including Macquarie Street (2C/1G), College Street (4C/6G) and Crown Street reservoir (0C/14G). Other eastern suburbs sites tested negative. However, a site at Rhodes tested positive also (0C/4G).

On Wednesday 29 July, samples received early in the day from Potts Hill reservoir showed two all clear and one with a low count (2C/5G). Later in the day, sample results from the CBD showed five sites clear and low counts at Art Gallery (4C/0G), College Street (2C/0G), Macquarie Street (1C/0G), Crown Street (1C/1G), corner of Liverpool Street and Hayden Place (21C/3G) and Centennial Park reservoir (7C/1G).

Late that afternoon a sample result from the sediment at Prospect Water Filtration Plant clear water tank Number 1, which was offline, showed a high positive (96C/42G per 4 grams of sediment). Later that evening, further results taken from samples earlier in the day showed positive results throughout Potts Hill reservoir (highest reading at the centre of the reservoir was 10C/48G), the City Tunnel (24C/27G) and further down the Pressure Tunnel at Enfield (12C/136G). Another low count at Rhodes, sourced from the Potts Hill reservoir, was also received (1C/1G).
In light of these positive readings at sites beyond the eastern CBD, a public alert was issued advising people serviced by the Potts Hill system to boil their drinking water. This was defined as "an area east of Bankstown Silverwater; south of the Harbour and north of the Georges River".

On Thursday 30 July, test results showed high positive readings at a number of points in the distribution system. These included Palm Beach (365C/151G). At this point, a precautionary boil water advice was issuedo for the entire Prospect system. Positive readings were also received at Warragamba pipeline Number 1 (409C/70G), which was immediately closed, Prospect clear water tank (765C/230G), Prospect distribution chamber (325C/75G), main City Tunnel (961C/333G), Macquarie Street (485C/232G) and Oakville (208C/144G). Three positive readings were received at Potts Hill (the highest of which was 273C/109G).

On Friday 31 July Minister Knowles, after meeting with the Premier, announced the formation of an expert panel to advise on when the water supply was safe. The panel comprises Australia's leading experts in infectious diseases and microbiology. It is responsible for reviewing all test results as they become available and advising on the criteria to decide when it is officially safe to drink the water.

Further high positive results were received on 31 July from samples taken on 29 July, including Cronulla (268C/8G in 15 litres) Crown Street reservoir (170C/0G and 32C/24G at different points during the emptying process), College Street (3150C/849G). Results of a sample taken on 30 July from Potts Hill inlet to the Pressure Tunnel tested positive (91C/46G in 30 litres).

On 1 August a positive reading was reported at Rhodes from a sample taken on 29 July (35C/7G in 15 litres). On 2 August positive results were received from tests in the preceding days at two hydrants (Bonnyrigg Heights: 6C/OG and Schofields: 20C/8G in 150 litres), Botany (52C/3G) and Centennial Park reservoir (2C/1G).

From Sunday 2 August to Tuesday 4 August, periodic announcements were made lifting the boil water advice for identified postcode areas on the advice of the expert panel. On 4 August the precautionary boil water notice was lifted for all areas of Sydney.

Second Event: Monday 24 August Saturday 5 September

Extensive raw water testing was undertaken from 5 August onwards, particularly of the source water of Warragamba and the Upper Nepean dams. Raw and treated water samples between 5 and 13 August were predominantly negative. On 14 August, high levels of *Cryptosporidium* and *Giardia* were reported from tests the previous day at the Inlet Channel to Prospect (8C/20G in 50 litres) and in Prospect's distribution chamber (50C/22G). Prospect's distribution chamber and the junction chamber tested positive in tests on 14 August (15C/16G and 27C/13G respectively).

The expert panel considered these readings but decided against the issue of a boil water alert. Testing showed that the organisms were dead, but confirmed that there was a continuing source of pollution.

On 21 August tests that day showed positive results in Prospect's finished water (37C/3G in 125 litres). There was also a low reading at Potts Hill Reservoir (2C/0G).

The Second Event commenced on 24 August when very high readings were reported in the Inlet Chamber to Prospect (94C/4G in 20 litres). Test results received the next day showed high positives in Prospect's finished water (863C/252G in 80 litres), at Palm Beach (1050C/347G) and again at Sydney Hospital (270C/39G). High levels of contamination were also discovered in the raw water at Warragamba dam (522C/11G in 30 litres). Positive readings were received in the distribution system on 25 August, the highest at Darlinghurst (370C/22G).

NSW Health issued a boil water alert for the whole area serviced by the Prospect plant on 25 August.

On 26 August, high levels were detected in the raw water including two readings in the Inlet Channel to Prospect (400C/81G in 25 litres and 530C/183G in 10 litres) and Warragamba dam (287C/15G in 25 litres and 130C/76G in 10 litres). High levels were reported on 27 August in Prospect's distribution chamber (140C/60G) and in the finished water leaving Prospect (31C/12G and 20C/4G).

Very high readings were taken from the raw water on 27 August including downstream of Moss Vale sewage treatment plant (25C/13G in 10 litres). Other high readings were received in Prospect's clear water tanks (1348C/467G), two readings in the Inlet Channel to Prospect (1417C/7G in 20 litres and 2094C/211G in 20 litres) and Orchard Hills reservoir (856C/52G in 90 litres). Finished water results included extreme readings in Prospect's finished water (81C/26G in 20 litres and then 1889C/455G in 20 litres) and in the distribution chamber (52C/11G). Positive results were also received in the suburbs of Cranebrook (14C/1G) and Glenbrook (11C/0G in 80 litres).

On 27 August, the boil water alert was extended to the areas serviced by the Orchard Hills and Warragamba filtration plants.
On 28 August there were positive readings recorded in the finished water at the Woronora plant (1C/3G in 60 litres) and the Macarthur plant (24C/2G). High levels of contamination continued at the inlet to Prospect (151C/37 G in 10 litres and 280C/98G in 10 litres).

Between 29 August and 3 September, the majority of tests were clear. The maximum levels detected were 1C/1G.

On 1 September, the boil water advice was lifted for some postcode areas and more, but not all, areas were cleared over the next three days.

Third Event: Saturday 5 September Saturday 19 September

On 5 September, high positive readings for both *Cryptosporidium* and *Giardia* were received from samples taken the previous day at Prospect plant in the raw and filtered water (500C/3500G in the filtered water). High levels were also detected in Warragamba dam pipeline (502C/381G in 5 litres of raw water). Tests from the same time showed very high levels in the distribution system at Pennant Hills (29C/33G in 10 litres) and Castle Hill (37C/1368G in10 litres). The clear water tank at Orchard Hills plant also tested positive (10C).

A boil water alert had been in force for areas of Sydney since the Second Event. On 5 September, NSW Health reinstated the boil water alert for all Sydneysiders and extended it for a further two weeks in response to fluctuating readings and to allow health surveillance to continue.

On 7 September, results from tests the previous day showed low levels of *Cryptosporidium* in Prospect's finished water and low levels of both organisms in Woronora's finished water (2C/7G). Samples taken at the same time showed high levels at Cherrybrook (75C/131G in 10 litres) and at Winston Hills (28C/39G in 10 litres). Moderate levels were detected in the finished water at Prospect

on 9 September (25C/30G). High levels of *Cryptosporidium* and *Giardia* were also found in the raw water in the Upper Canal, in Warragamba and Cataract dams and at the Macarthur plant. On 10 September further high readings were reported in Prospect's finished water (47C/63G).

On 11 September, contamination was found in the finished water at Prospect, Nepean, Macarthur, Woronora, Illawarra and Orchard Hills filtration plants. As discussed in Chapter 7, I have considerable reservations about the reliability of these results.

The next positive reading in treated water was from a sample taken on 13 September at Prospect in the finished water (2C/24G). A further low reading was found in the finished water the next day (2C/7G). Macarthur plant tested positive for *Cryptosporidium* on 16 September (1C/0G). The final positive finding in treated water was at Prospect on 18 September (2C/0G).

On 19 September, following advice from the expert panel, the alert was lifted for all of Sydney.

- forestry 3,280 tonnes;
- land rehabilitation 9,020 tonnes;
- research 30 tonnes; and
- landfill 741 tonnes.

The sludge may be composted, although the majority used is treated with lime and given up to 20 days retention time in an anaerobic digester at 30 degrees Celsius. This treatment is considered sufficient to kill pathogens and other harmful organisms.

While most of the pathogens are killed, research has shown that *Giardia* cysts are still capable of detection in biosolids for up to six months and at high levels (McInnes et al, 1997). *Cryptosporidium* oocysts survive better than *Giardia* cysts and therefore are likely to be detectable for an even longer period of time.

Sydney suffered a significant outbreak of cryptosporidiosis in late 1997 and early 1998 and its sewage is likely to have been heavily contaminated with the pathogen. Furthermore, background levels of *Giardia* are always present in sewage, so large numbers of both organisms would be expected in biosolids produced during this time.

Investigations of biosolid application in the Warragamba catchment has revealed that a total of 5,378 tonnes was applied during 1997/98. A total of 5,328 tonnes was applied to three grazing properties and 50 tonnes to the degraded Woodlawn mining site. All of these applications were subject to EPA licences and met their conditions. However, these conditions do not include any criteria for *Cryptosporidium* and *Giardia*.
Sydney Water and NSW Agriculture have undertaken research which shows that biosolids improve infiltration of water into the soil and reduce erosion. Close monitoring of water quality downstream of large biosolid applications has not shown any deterioration in water quality, however this research was limited to faecal coliforms and Eschrichia coli and did not include testing for the pathogens. Further research is proposed.

While Sydney Water may be correct, the levels of *Giardia* identified in biosolids by other studies provide a significant reservoir of inactive pathogens that could be released by rain and washed into watercourses and reservoirs. *Giardia* concentrations of 640 cysts (Soares et al 1992), 2,000-5,000 cysts (Thiriat et al, 1996) and 38,000-140,000 cysts (Gibbs et al, 1995) have been found in one gram (dry weight) of anaerobically treated biosolids. This has the potential to provide a vast reservoir of inactive parasites capable of recording positive results if released by rain and washed into the Warragamba dam.

This could explain the extremely high numbers of *Cryptosporidium* and *Giardia*, but the lack of illness in the community, during the Sydney events. This could also explain the low level of faecal indicator bacteria as they would have been destroyed by the treatment of the sludge. Sydney Water is commissioning further work to test the persistence of *Cryptosporidium* and *Giardia* in biosolids.

Stormwater run-off

As well as sewerage systems which take wastes from homes and businesses, there is a separate drainage system that carries away excess water from gardens, roads, footpaths and roofs of buildings in urbanised areas. Stormwater, or urban run-off, refers to the rain run-off from all sources. In most cities and suburbs, there are roadside drainage pits where rainwater run-off can enter the underground stormwater drainage system.

Most drainage water flows directly into waterways, causing pollution. In some cases, stormwater run-off can be more toxic than treated sewage released from STPs. The pollution contained in urban stormwater can include: sediment from development and new construction; oil, grease and toxic material left on roads by cars, such as lead, zinc and copper; nutrients and pesticides from lawn management and gardening; and viruses and bacteria from failing septic systems. The faeces of domesticated animals such as dogs may also be a major source of pollutants in stormwater, and also a potential source of *Cryptosporidium* and *Giardia*. Sewer overflows may also be picked up and transported by stormwater.

Responsibility for the management of stormwater is fragmented between State and local government bodies. Stormwater systems in the catchment are primarily managed by local councils. The EPA has recently developed a policy framework and best practice guidelines requiring councils to develop stormwater management plans.

Native and feral animals

Feral deer, pigs, goats, wild dogs, feral cats, foxes, horses and cattle infest parts of the catchment. Studies are being done to see if they carry human-infective *Cryptosporidium* and *Giardia*, but no conclusive results are available. Nonetheless, such animals are all potential carriers of these parasites, as are native animals such as kangaroos, wallabies, possums and koalas (Gasser and Morgan, 1998).

The National Parks and Wildlife Service has responsibility for feral animal control on the national park estate. It is also involved in joint control programs with Sydney Water in Inner Catchment lands. It is difficult to assess either the number of feral animals in the catchment or the effectiveness of control programs.

Little information is available to assess the number of native species to determine whether there has been any significant variation in numbers leading up to the contamination event. However, large numbers of kangaroos have been reported around the foreshores of Lake Burragorang as a result of the recent drought.

Other sources

There are a number of other sources of faecal contamination that pose a threat to the catchment. These include:

- public toilets located at recreation facilities on the river system, for example, at Avon, Cataract, Cordeaux and Nepean dams which are visited by approximately 1,000,000 people annually;
- illegal fishing in Lake Burragorang and Cataract;
- possible accumulation of *Cryptosporidium* and *Giardia* in sediments in Lake Burragorang; and
- swimming pool and water treatment plant discharges, both of which can contain concentrated sources of *Cryptosporidium* and *Giardia* swimming pools are located at Nattai, Wollondilly and Coxs River (EPA, 1993).

Conclusions on possible sources of *Cryptosporidium* and *Giardia*

It is clear that contamination of raw water entering the Prospect plant was a major cause of the recent events, especially the Second and Third Events. The state of the catchment poses continuing serious risks for the safety of Sydney's drinking water.

The lack of data about the catchment and the current monitoring regimes makes it impossible to be definitive about the specific sources of the *Cryptosporidium* and *Giardia* which contaminated the raw water in July - September 1998. However, a joint working group comprising Sydney Water and Australian Water Services staff has ranked the sources of risk in the catchment that pose the greatest threat of contamination by *Cryptosporidium* and *Giardia* at levels which threaten public health (AWT, 1998a). The results of this work indicate that the highest risk sources are sewage treatment plants, unsewered and sewered urban areas near Warragamba Dam and grazing in areas near the Dam. Of the 13 point sources identified, the top 8 (representing 23 individual discharge points) relate to sewage treatment plants.

All of the sources listed above are ongoing threats to water quality and require urgent attention. Further research is required to create an accurate picture of the catchment's health. This work will need to analyse the risk posed by possible sources of contamination and review the following:

- magnitude of contamination;
- frequency of the discharge (continuous vs run-off related);
- type of contamination (animal or human); and
- distance from the lake and travel times during events.

Further information on possible sources

The Inquiry commissioned tests to try to identify whether the source of the *Cryptosporidium* and *Giardia* contamination was human or animal, in an attempt to determine in the recent contamination events.

The tests indicated predominantly herbivore faecal contamination in the dams, but also provided strong evidence of occasional human faecal contamination. It can be concluded that the bulk of the *Cryptosporidium* and *Giardia* detected was most likely to have come from catchment animals.

Verification tests were subsequently attempted (both in Australia and the UK) to attempt to confirm whether the *Cryptosporidium* was of human or animal origin. These tests were unsuccessful. This may have been because many of the *Cryptosporidium* seen were empty shells.

High numbers of parasites in raw water would normally have been associated with other faecal indicator microorganisms. However, consistently low numbers of faecal indicator bacteria in the raw water were reported by AWT during the Events. A possible explanation is that the source of the faecal material was so old that the indicator bacteria had died out, although the *Cryptosporidium* and *Giardia*, which are very resilient, were still detectable. The low levels of faecal sterols measured supports the possibility of a distant source of faecal contamination and the lack of infectivity would support this view.

These findings suggest significant contribution to the recent Events was faeces from animals. This would have accumulated on the land over a period of time in the drought and washed into the watercourses during the unusually heavy rainfalls.

This does not mean that other sources can be disregarded. Other possible sources of faecal contamination, such as overflowing STPs and unsewered areas very close to the dam, are likely to have contributed pathogens to the raw water stream in the recent contamination Events. These, and sources of other pollutants such as mines and industrial sites, are ongoing threats to the protection of water quality in the catchment.

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Chapter 6: The cause of the Events

What caused the contamination events?

The First Interim Report identified a number of possible causes of the first contamination event. The Second Interim Report provided an update and commented on causes surrounding the Second Event. The Third Interim Report contained a detailed assessment of the catchment and possible sources of contamination. It also examined the performance of Sydney's filtration plants.

During the course of the Inquiry all available expertise in catchment management, limology, hydrology, treatment and science has been applied to identifying possible causes. Much has been learnt but some matters can still not be fully explained.

There is general agreement on some aspects of the cause of the events but strong disagreement on others. This chapter traces the water system, from source to tap, examines the possible causes identified in each element of the system and discusses their possible impact on the three contamination events.

Catchment

There is general agreement that the catchment is compromised. The possible sources of the parasites are outlined in detail in the previous chapter. They include:

- sewage treatment plants (STPs);
- sewer overflows;
- septic systems;
- domestic animals;
- biosolids;
- stormwater run-off; and
- native and feral animals.

It is also clear that the sources of the parasites were both human and animal waste. Their transportation in the raw water through the system was the primary factor in all the Events.

Climate

Climate can have a considerable impact on the presence of the organisms. The drought over recent years meant there was limited mobilisation of *Cryptosporidium* and *Giardia* from the potential sources within the catchment. It would have resulted in a substantial build up of contaminated material on river banks and in streams. This large reservoir of *Cryptosporidium* and *Giardia* once mobilised would have been a major contributor to contamination within the system during the three Events.

Rainfall events

In normal circumstances, most of the potential contaminant load within the catchment does not enter watercourses.

Contaminants are contained and treated in STPs or lie dormant on land. The small amounts which enter the water courses and dams mostly settle to the bottom or are removed in the filtration processes at the Prospect plant.

However rain events can mobilise the *Cryptosporidium* and *Giardia* particles and introduce them to water courses. At times of heavy rain STPs are more likely to overflow, septic tanks to overfill, and runoff from agricultural land and unsewered urban areas to increase. If the levels of *Cryptosporidium* and *Giardia* entering water courses are high and the inflows into the dams are large, there may be limited time for the particles to settle and treatment plants may not be able to remove all of them.

Intense rainfall can have a significant effect on raw water quality, particularly after periods of drought. Rainfall and/or snow melts have been a consistent contributor to most overseas contamination incidents. During these events contaminated material is swept into streams, rivers and storage facilities.

Some of the rainfalls in the Warragamba catchment during the recent Events are set out in the following table.

Table 1: Rainfall in Sydney's catchments during the contamination events (in millimetres)

Date	Bowral	Camden	Katoomba	Wollongong
03.06.98	15.2	7.0	28.0	6.0
04.06.98	2.2	6.0	24.0	31.0
23.06.98	50.4	49.0	49.0	Nil
21.07.98	28.0	17.0	19.0	Nil
07.08.98	25.6	25.0	39.0	40.6
08.08.98	114.8	62.0	159.0	136.4
16.08.98	21.8	44.0	39.8	79.6
17.08.98	39.2	58.0	44.2	32.0
18.08.98	60.8	50.0	17.2	316.0
19.08.98	34.6	4.0	1.0	99.0

Both the 23 June and 21 July rain events, which were the first heavy real rain since July 1997, resulted in increased flows into Warragamba dam and increased water levels within the dam.

The heavy rainfall in August also caused overloading of the sewage treatment plants at Goulburn, Bowral, Mittagong, Bundanoon and Berrima, in the catchment. The Goulburn plant was unable to irrigate its treated effluent which was released into the Wollondilly River. Sludge ponds at Bowral were flushed into the river and the Bowral, Mittagong, Bundanoon and Berrima plants were all required to operate at extraordinary levels. The consequence was that significant volumes of poorly treated sewage were released into the Wollondilly River and entered the dam.

There is also evidence of the introduction of contaminated material into the Coxs River. The Wollondilly and Coxs River together comprise in excess of 60% of the flow into Warragamba dam.

There is little doubt that the inflow from the rain events was heavily contaminated.

Dams

Water storages, such as Warragamba dam, can operate to naturally remove *Cryptosporidium* and *Giardia* before water enters treatment plants. If water is stored for extended periods, parasites may die off or be locked into sediment as they settle on the dam bed. Poorly managed storages, however, can create conditions in which oocysts and cysts cluster at certain temperature zones within the dam. Concentrations of the parasites can then be rapidly transported and fed into the intake point of the treatment plant, presenting it with a slug of highly contaminated

water.

The rain in June and July resulted in the Warragamba dam receiving 16,750 megalitres (ML) of water and rising 0.22 metres. The rainfall in August resulted in flood peaks and high inflows which dramatically increased water levels and caused the dam to spill.

The dam filled in two very fast steps. Following two days of heavy rainfall, from 7-9 August, it went from 58% to 83% full. Two weeks later, following two more days of heavy rain on 16-18 August, it went from 83% to 100% full. This type of rapid filling has never occurred in the history of the dam and is estimated to be a one in thirty year event.

Large areas of the foreshore (1,800 hectares) of the dam were re-flooded during these events. This would undoubtedly have mobilised a large volume of faecal matter which had been deposited on the foreshore of the dam by native, feral and domestic animals defecating at the water's edge over a period of more than six years, since the dam was last full in 1992. This material had the potential to carry very large numbers of *Cryptosporidium* and *Giardia* into the water of the dam.

Samples taken on Wednesday 26 August revealed high levels of contamination in the dam at various depths. Subsequent studies have examined the likely flows of contaminated water within the dam. This is largely determined by water temperature and wind. These create density differences through the water column which separate and partition matter within the dam. These studies demonstrated that a sharp temperature gradient known as a thermocline was operating which resulted in different layers of water density. Both the thermocline and the cold water immediately below it were found to contain high levels of *Cryptosporidium* and *Giardia*.

Wind and temperature changes within the waters of the dam generate internal waves at the level of the thermocline. The intermittent level of measured contamination may be explained by these waves causing the thermocline to periodically rise and fall through the depths at which water was being extracted to feed the Prospect plant. This is clearly demonstrated in the figure below which compares water temperature in the Warragamba pipeline and positive tests in the raw water during August. When warmer water was extracted from above the thermocline, almost no positives were recorded. *Cryptosporidium* has been found to survive more readily in colder water.

The concentration of contamination within the dam had the potential to feed slugs of contaminated water to the plant during all three Events.

Upper Canal and Warragamba pipelines

The Upper Canal brings raw water from the Upper Nepean dams to the Prospect plant. The Warragamba pipelines bring raw water from Warragamba dam to the plant. A number of possible causes of contamination were identified within these elements of the system.

Dead dogs and foxes found in the Upper Canal

The catchment is regularly patrolled and dead animals are found from time to time. They are a potential source of contamination of the raw water entering the Prospect plant. I am informed that some dead animals were removed from the Canal during the First Event and these tested negative for *Cryptosporidium* and *Giardia*. I do not believe they played any part in the contamination events.

Environmental flush of the Nepean River

On 7 July the Nepean River was scoured during an environmental flow test and the waters discharged into the Upper Canal and the Prospect plant. The flow rate in the river was increased for several hours and then reduced again. Because of concern about the low storage level, this flow was taken into the Upper Canal rather than allowing it to spill from the weir and proceed downstream. The flow in the Canal increased from an estimated 100 ML/day to approximately 400 ML/day. This significantly increased the scouring of material from the bottom and sides of the river and the Canal and fed it into the Prospect plant. If *Cryptosporidium* and *Giardia* were present, they would have been washed into the plant.

The turbidity of the treated water at the plant did increase slightly suggesting increased passage of particles. I am satisfied that this incident is likely to have contributed some *Cryptosporidium* and *Giardia* organisms to the system, but the timing and magnitude is not such that it could be the sole cause of the high levels found from 22 July.

Raw water turbidity events in the canal and pipelines

I am satisfied that the breaking of the drought and subsequent significant rainfalls resulted in increased runoff of contaminated material into the dam.Giardia across the Prospect system and it was likely that a boil water notice would have to be issued for that system later that evening. He was requested to make appropriate preparations immediately, to draft a media release and take steps to ensure that sufficient staff would be on hand to deal with the inevitable public relations difficulties.

Metcalfe tells me that Pollett came to him a little before 10:00pm and asked about the media release. He looked at a draft which contained a warning for the whole of the Prospect system. Pollett did not change the draft. He told Metcalfe to run it past NSW Health and "get them to sign it off". Metcalfe says he spoke to Armistead at 10:15pm and again at 10:25pm. Armistead says he only called once, at 10:25pm. At that time he read her the release and she requested one change.

Metcalfe was aware that the media release needed Pollett's ultimate approval and could change from his original draft. However, he says that he was never given to understand that there could be any change in the area to be affected. His understanding throughout was that the alert would be Sydney wide.

Pollett has a different recollection of the sequence of events. He says that after his unsuccessful call to Hill at 9:31pm, he spoke with Metcalfe saying:

POLLETT: "Please prepare a draft media release for 'boil water' along the lines of Monday's release in the CBD. You should consult with Shari Armistead of NSW Health in preparing the draft. Sydney Water is going to release the statement as we did on Monday. I'm going to get advice from our General Managers and other experts on what areas are affected. When you prepare the draft media release, please include, at the moment, the whole of Sydney, but not Blue Mountains, Illawarra, Penrith, North Richmond and Macarthur."

Metcalfe does not suggest that Pollett asked him to draft the release. However, it is apparent that at least Pollett read Metcalfe's draft which covered all of Sydney. Whatever the correct sequence of events might be, it is apparent that before Hill arrived, Pollett had accepted that preparations should be made on the basis that the health alert may be for the whole of the Prospect system.

Pollett goes to the operations room

After speaking with Hill, Pollett went to the operations room. He says he joined the discussion and recalls debate about the role of Prospect plant in the contamination. The meeting remained unsure as to the area that might be affected. No further data was available. There were two matters that needed to be considered. First, the source of the contamination had to be identified and, if possible, dealt with. Secondly, and of greater urgency, was the need to release an appropriate health alert.

I have been told by the executives that, even after having talked over the matter for several hours in the operations room, they had been unable to conclude a view about the likely sources of the contamination or, more significantly, the most appropriate health alert. If this is correct, they were obviously unable to give Pollett clear advice.

Each of the executives gives a slightly different impression of the meeting.

Mackender tells me that, by the time Pollett came into the room, he knew they had a large problem at Potts Hill, and a potential problem at Prospect. He says this was explained to Pollett. He tells me he was not asked to advise in relation to possible health warnings although this was discussed around the room. His impression was that the view of the room, being the view of the technical people, was that all of the Prospect system should be warned. However, he could not confirm that other individuals were of that view. Some obviously maintained that it could be a localised incident.

Quill arrived during the discussions. When he arrived in the operations room, Pollett was present. Quill tells me that the discussion had now become centred upon the extent of the boil water notice which should be issued. He said that he agreed with the idea that the contamination had come through Prospect and that the whole system was a risk, but says the extent of an alert had not been resolved before Hill arrived.

Hill arrives

Hill arrived a little after 10:00pm. He first went to the 23rd floor, where the Boardroom, Managing Director's office and media people were located.

He says he heard a:
HILL: "tremendous amount of noise."

and observed about six people in a high state of excitement.

It was:

HILL: "not a situation that I would say, in management terms, is under control."

I have no doubt his description is correct.

Hill tells me that he overhead one of the media people asking her superior whether the Department of Education should be alerted. Hill intervened to tell her that she should not phone anyone yet. Before going to the operations room he asked whether any media statements had been issued. He was told that there was a draft, which was awaiting Pollett's approval. He looked at the draft and noted the words 'severe diarrhoea' and 'urgent'. He thought the language alarmist but says he did not take particular note of the area identified in the alert.

Metcalfe told Hill that he was liaising with NSW Health on the media release, but otherwise it had not gone to any other person. Certainly nothing had been released to the media.

Hill goes to the operations room

I have a number of accounts of the events which occurred when Hill went to the operations room. McCarthy indicates that Hill arrived and said:

HILL: "I hope you blokes know what you're doing."

HILL: "Do you realise that what you're doing here will affect the organisation for the next 10 years, and probably longer than that."
McCarthy described these as very challenging statements.

Quill recalls that in his opening remarks Hill appeared to be questioning whether an alert was necessary at all. His recollection is that Hill came into the room and the first thing he asked was:

HILL: "Why do we need to issue a boil water notice?"

Quill infers that Hill did not understand the process, or the rationale behind a boil water alert. It was explained to Hill that it was because of the high levels. Hill then indicated that he wanted more information.

Mackender's recollections

Mackender confirms that he used a large map to explain the test results and their consequences. He says that throughout the discussion Hill repeated, on a number of occasions, the words:

HILL: "Tell me the facts." "Where have you actually observed this parasite? Where have you actually observed it?"

The response was:
MACKENDER: "Well, it's here and here."

And at one stage Hill apparently said:

HILL: "Well, you're talking about a narrow strip towards the city."

Mackender says he took time to point out to Hill that the strip was a tunnel with various offtakes. Having identified contamination at Enfield, there were areas north and south of the tunnel which would be likely to have contaminated water.

Mackender says he told Hill about Prospect and there was a discussion about its relevance. Hill said:

HILL: "Have you got any observations there which indicate there's a problem?"

Mackender said they had clear readings downstream at the Prospect plant although they already had experience with clear readings being obtained from areas that were later shown to have been contaminated. He was not prepared to conclude from those clear readings that Prospect was not the source of the contamination.

At one stage Mackender tells me that Hill said:

HILL: "I don't want to know about your theory, I want to work on the actual data you've got where there is a problem."

I understand this to mean that he wanted to know about where contamination had actually been measured. This is confirmed by the transcript of my discussion with Mackender.

QUESTION: "You say you told him that the system had a problem..."

MACKENDER: "A potential problem."

QUESTION: "... at Prospect."

MACKENDER: "At Prospect, yes."

QUESTION: "And you gave him to understand that that could affect the whole of the system."

MACKENDER: "Yes. Yes, yes, that's true. Speculation is what I was told that was."

QUESTION: "Sorry?"

MACKENDER: "His comment was that that was speculation."

QUESTION: "He said that's speculation."

MACKENDER: "That's right, yes."

QUESTION: "What did you say?"

MACKENDER: "I said, 'That's my best technical assessment of what could happen.' "

QUESTION: "Was there a disagreement between you and Mr Hill?"

MACKENDER: "Very hard to no, I don't think there was a disagreement. I think he listened to what I had to say and took the bits that he wanted to hear and made a decision. Now, he may have put less weight he may have put

less weight on my "speculation" and more weight on the part where we had numbers but that was the way he makes maybe that's the way he makes a decision. He didn't say to me, he didn't try and convince me..."

QUESTION: "No."

MACKENDER: "... that this was an action he should take or that that was an action he should take. He was collecting information off me and putting weight on it based on whether he believed me or he didn't believe me or whether he thought I was technically competent or incompetent."

QUESTION: "Did he communicate his decision to you..."

MACKENDER: "No."

After this discussion Mackender says that Hill and Pollett left, Hill saying

HILL: "I feel like a cup of tea. We'll go and have a cup of tea Chris."

They then left the room.

The impression I have is that Hill and Pollett left abruptly with others in the room being uncertain as to what would happen next. By Mackender's account, no decision had been made as to the area of the alert before Hill and Pollett left the operations room.

Pollett's recollection

Pollett gives an account of these events. He says that, by the time Hill arrived, neither he nor the meeting had a concluded view about the extent to which there should be an alert. He says:

POLLETT: "My recollection my recollection is that we were still talking about I mean, it was early days. I mean, it's not very long. I mean, this is a rapid response to a situation to get everybody into the office. People were still coming in, coming and going. Phones were ringing, information was being collected, etc. etc. so I certainly don't recollect the meeting, say, 'aha, it's that or something else'. Sure."

Pollett says that on entering the room Hill said:

HILL: "We need to consider this carefully we don't want to cause undue alarm."

Pollett says Hill stated that opinion:

POLLETT: "very clearly, very strongly."

Hill's recollection

Hill's recollection of the events is quite different to that of the executives. He says that he spent only a short time, 5-10 minutes, in the operations room. He says that his first action,

HILL: "bearing in mind the bedlam I had observed on the 23rd floor"

was to say to Pollett,

HILL: "We should calm everybody down, tell them to have a cup of tea and send most of them home."

Pollett wisely did not take his advice.

Hill says that when he arrived in the operations room, Pollett said to him:

POLLETT: "We're trying to calculate what areas are at risk. We found positive results for both *Cryptosporidium* and *Giardia* at Potts Hill and Enfield. But we've also found some zero results in other areas. We've got to issue a boil water alert but we have to calculate for what areas that alert should be issued."

Hill tells me:

HILL: "The advice I got then from Chris and subsequently was that they were trying to calculate on the basis of where they'd got positive results as distinct from negative results, what areas of Sydney could be at risk as distinct from those where there was no evidence that they were at risk and I concurred."

Hill also tells me:

HILL: "Given my lack of technical expertise, I could not make any useful contribution to the calculation which was being conducted."

He considered that the approach being followed by Pollett and his managers was proper and responsible.

HILL: "In my view it was not responsible to force people to boil water unnecessarily."

He says:

HILL: "They did try and explain it to me but I brought absolutely no skill to that, no qualifications for that. I didn't then, and I don't now understand where all the pipes run ... I couldn't make that calculation and I couldn't even make a contribution to the calculation so I accepted their advice."

He says:

HILL: "They may have explained things to me but it was really immaterial to me."

He agrees that he did say that the matter was serious.

HILL: "I said "This will do irreparable damage to the company for a number of years ... if it ever recovers. But that was, I think, prophetic, wasn't it?"

When asked whether he thought that his intervention may have influenced the situation, he says:

HILL: "I don't think in any way it would have influenced them in any improper way, no."

When asked about Prospect, he says:

HILL: "I have no recollection of anybody mentioning Prospect."

When asked whether they mentioned bypassing Prospect at any time, he says:

HILL: "That night, no."

When asked how it came about that he and Pollett left the meeting, he says:

HILL: "I had nothing to contribute to the exercise, the exercise was determining what parts of Sydney were at risk as distinct from those that weren't. So there was absolutely no point in me staying there and I was aware that I would contribute nothing. So at whatever point I left, it was at the point that I realised I could make no contribution to that process."

He was asked about the events:

QUESTION: "Right, but you wouldn't have said anything that might have led them to understand that you thought the right decision was to limit the area."

HILL: "I was of that view that on the basis of their advice to me that that's why they were on the 19th floor. They were trying to calculate before I got there, they're trying to calculate, based on the distribution of the negative test results and the distribution of the positive test results, what part of Sydney should be put on a boil water alert. Their exercise. Their decision. I took advice on it. I was of the view that was the proper course to take but they had better get it right, they better do it quickly, and if I expressed that I may have expressed that view to them. I was certainly of the view, then and now, that if they were persuaded that on the basis of the distribution of negative test results there were large sections of Sydney that were not at risk then it was a responsible course not to put them on a boil water alert. Now, I was of that view and I may well have expressed that view."

On leaving the operations room, Hill and Pollett went to the Boardroom. He was asked about these events.

QUESTION: "At your initial time in the Boardroom when you first got there, as I understand what you're telling me, you didn't know of any decision having been made. It could have been Sydney-wide, it could have been..."

HILL: "It could, yes. No, I'm sorry, no. When we went to the Boardroom, I drew the box because I had been advised that not all of Sydney, and they were still trying to refine or define the areas, but I had been advised and I relied on the advice 'not all of Sydney is at risk.' "

QUESTION: "Were you advised of that in the boardroom?"

HILL: "No. I was under the distinct impression that that was the advice I got when I was still on the 19th floor, that it wasn't all of Sydney but they're trying to define or designate the areas at risk. 'Designate' was a word that Chris used, but it was to define the area. But I was told when I went down to the 19th floor, not all of Sydney was at risk. It was a question of how much was and how much we would have to issue the alert. So they hadn't provided the boundaries. They were still trying to calculate the boundaries of the affected area. But I was clear in my that's the advice I took when I went back to the 23rd floor and started drafting this."

Reid calls Pollett for an update

Pollett says he was called out of the discussions in the operations room to answer a call from Reid, who inquired as to the source and cause of the contamination. When interviewed, Pollett says he told Reid:

POLLETT: "Well, it could be this, and it could be this, and it could be this, all the way down the system. You know, it could be some stuff being washed out of a catchment. It could be something washed into a canal. It could be the operation of the [Prospect] plant. It could be sediments in Potts Hill reservoir because I have known a year ago we had had sediments, samples taken in Potts Hill and received some levels. I was still worried about biofilm because the flushing experience in the eastern CBD."

His written statement also confirms that Prospect may have been the source of the problem.

POLLETT: "I informed him that the causes were not known at that stage but mentioned some possibilities to him including naturally occurring *Giardia* and *Cryptosporidium* in the catchments and raw water, the operations of the Prospect plant, and ingress of *Giardia* rich water into storage canals, sediments in the Potts Hill reservoir, ingress of surface water or other objects into Potts Hill reservoir, or other reservoirs, and bioflims in the pipelines. I informed him that we were still assessing the data and discussing the areas which could be affected.

It is plain that, even if there had been a misunderstanding about the earlier conversation, after this conversation Reid was entitled to believe that the alert should be for the whole Prospect system. At this point it was imperative that a revised health warning should be released and, as the Prospect plant was a possible source of contamination, appropriate action for public health required that a warning be issued for the whole Prospect system.

Pollett says he made the decision.

Pollett says that, on leaving the operations room, he had not resolved the area that might be affected by a health warning. He says:

POLLETT: "I was still considering it in my mind. It would probably be fair to say that I had formed the view that we only had data from Potts Hill downwards because we talked about Potts Hill, Enfield, city tunnel. I remember asking questions: 'Do we have any other data?' There were people saying: 'Yes, we have some recent data that shows zero.' "

He says that he was aware of the reading in the sediment at Prospect plant but understood the tank was offline.

He acknowledges that the envelope of possibilities certainly included Prospect. He further says that when leaving the meeting he was:

POLLETT: "forming an opinion in my mind that given the particularly the views that we shouldn't and I think it's mentioned here. David certainly put the view that we should go I'm not sure what words I have used, but it was something like 'the minimum area that could be demonstrated based on the facts."

Pollett's view of the impact of Hill's presence in the room was stated to be that Sydney Water should be cautious and not alarmist. He tells me:

POLLETT: "If we had data that showed a certain area, we should use that, reach conclusions on those data but the other thing that was going through my mind, as he was talking about not being alarmist by declaring areas that couldn't be clearly supported was the fact that my experience in the water industry, particularly in the UK with boil water notices, where they have quite a bit more than we do, the view there is that you do need to be cautious and they have evidence, they told me, that you can get quite a lot of injuries from boiling water, particularly with old people and young people and, you know, you need to be cautious about not overdoing it."

Pollett says he heard Hill's comment that the alert could damage the Corporation, although he denies that his thinking was influenced by that. He says that he realised that Hill had the clear view that:

POLLETT: "We shouldn't be alarmist and should go with the area that we could justify on the data."

Pollett says that, if further information had come through the following day, which suggested a wider area might be affected, then the opportunity to extend the alert would be available.

POLLETT: "I wasn't particularly concerned about an all or nothing type decision. I knew that as we had more information it would be quite prudent and diligent the following day to say, 'All right, well, we'll add some more.' "

Pollett denies he allowed Hill to make the decision.

POLLETT: "In my mind he was clearly leaving the decision to me, the ultimate decision on the area to me."

He says:
POLLETT: "It never occurred to me to leave it to the Chairman to make a decision."
Pollett gave me a written statement after he had an opportunity to reflect on the matter and before any issue as to effective management of the crisis had been discussed with him by the Inquiry. It gives a different emphasis to the role of Hill.

In paragraph 23 of his written statement, Pollett says that when he and Hill went to the Boardroom, the following was said:

HILL: "The precautionary notice should cover only affected areas which can be supported by facts and data. To go wider would be reckless and cause unnecessary alarm. Also it should only refer to *Giardia* because of Health's media release to the Sydney Morning Herald on 28 July". (This meant that any reference to *Cryptosporidium* the

potentially more dangerous organism, would be deleted.)

POLLETT: "As we discussed downstairs with our experts, it appears that on the information received and the sample data now available there are recent clear results in water from the Prospect plant as well as other areas being fed by the plant. On the present data, the area affected is the Potts Hill system."

When interviewed Pollett gave further explanation of these events.

QUESTION: "When I look at paragraph 23 of your statement..."

POLLETT: "Yes."

QUESTION: "... am I to understand that it was after that conversation that you made the decision?"

POLLETT: "Well, that was the point at which I mean, that's when we were sitting down to draft the release and I suppose what I'm saying here is that's, that's the point. I mean, having been through the thoughts that I have just described I had clearly formed a view in my mind that the Potts Hill area was the right ..."

QUESTION: "Was that when you communicated your decision to Hill? That seems to be."

POLLETT: "Yes, that's, that's what I recollect."

It has been submitted to me that the remarks which Pollett attributes to Hill in his statement should be understood as policy advice. Bearing in mind Hill's earlier apparent dismissal of information relating to Prospect as theories or speculation, I doubt that his advice could be construed as policy. Although Pollett may have made the actual decision, Hill defined its parameters. There would be few Managing Directors who would make a decision which the Chairman described as reckless.

Morris' recollection of the decision

Morris' account is important. He says that, a short time after Hill and Pollett left the operations room, he also went to the 23rd floor. He was called into the Boardroom where Hill was altering the draft of the media release, which Metcalfe had previously prepared. He says he was asked "help us with the wording on this we have decided to go with the Potts Hill system".

Being unsure as to how the Potts Hill system should be described, Morris went back to the control room to discuss with the other executives the precise form of wording which should be used.

NSW Health issues a media release

After Hill and Pollett had gone to the Boardroom, they were interrupted and told that NSW Health had already issued Sydney Water's draft media release giving a Sydney wide alert. Armistead had done this on Reid's instructions but without Sydney Water's knowledge. It was read on the late evening news.

Hill was "appalled", being of the view that unilateral action by NSW Health was the "height of irresponsibility". Hill asked that Armistead be contacted by telephone and asked to retract the media release.

Metcalfe made contact and Hill took the phone. Hill's account of the conversation is as follows:

HILL: "I said in the telephone 'This is irresponsible. It's unauthorised and inaccurate.' Armistead said 'You people should have put the release out earlier. That's why we put it out.' I said 'You're in enough shit already. Don't argue. Just retract the bloody thing and get Mick Reid to ring me'. Then I hung up."

Armistead gives a different account of the conversation. She says, at various stages, Hill "shouted", "yelled" and

"screamed", "adopted a threatening tone" and "berated her personally". Hill denies this and says Armistead was "argumentative" and "belligerent in tone".
It was obviously a heated exchange. However, I am satisfied that Hill did not say "I will sack you" although he accepts he may have said words to the effect "you'll be sacked". He certainly said to those in his media office "she should be sacked".

I am satisfied that Armistead acted on the express instructions of her Director-General. Hill's actions did not enhance the prospects of effective communication between the two bodies then or in any future crisis.

The media release is "killed"

After finishing his conversation with Armistead, Hill asked Metcalfe to "kill" the release as quickly as possible, because it was alarmist and inaccurate.
Metcalfe immediately contacted AAP as the prime source of radio and newspapers for the evening. He spoke to the news editor who he told to "kill the story" stating "that it was inaccurate and wrong."

The effect of the attempt by Hill and Pollett to "kill" the media release was to cause confusion and undermine public confidence. This became obvious from the media response the following morning.

Hill speaks to Reid

At about 11:40pm, Reid rang Pollett. Pollett told Reid that Sydney Water had asked for the retraction of the media release and that a modified release had been prepared and issued. He also expressed concern at the lack of consultation with Sydney Water before Armistead had released the draft media statement.

Hill then spoke to Reid and tells me he said:

HILL: "The Department has behaved with the ultimate irresponsibility. Your people, without authority, have released information on a serious issue that is inaccurate."

I understand that Reid was not aware that he was speaking to the Chair of Sydney Water, made a curt reply and terminated the call.

The media release is issued

Hill and Pollett sat together to redraft the media release. A copy of the draft is in the appendices, showing Hill's annotations. Hill took out the reference to *Cryptosporidium* in the draft because of his understanding of a statement issued by NSW Health on
28 July, part of which had been quoted. This had the consequence that the most potentially dangerous organism was not referred to in the release issued by Sydney Water that evening. NSW Health later approved this revised release. Whatever may be the medical debate about the effects of *Cryptosporidium*, it was in my opinion inappropriate to delete reference to it from the release.

Sydney Water issued the revised release at 11:40pm. It is also in the appendices. Later in the evening Pollett phoned Reid to assure him of future cooperation. Pollett also phoned his Minister to inform him of the latest actions.

Thursday 30 July

The Minister becomes involved

Minister Knowles assumed a major role in managing the incident from the morning of Thursday 30 July. This report explains some of the difficulties he faced.

The Minister's involvement until this point had been limited. He was first advised of the contamination findings in the eastern CBD by Pollett at 2:00pm on Monday 27 July. At that time he was advised the cause was unknown but

could be the result of earthworks relating to the Eastern Distributor.

On the evening of Wednesday 29 July he received advice from Pollett that the contamination was much more widespread than initially thought, that the area of concern had been determined and a media release issued. He was not told of the difficulties between NSW Health and Sydney Water.

On the Thursday morning, the Sydney media gave prominent coverage to the situation. Not surprisingly they highlighted the confusion in the message. The media coverage emphasised the differences between the alert issued by NSW Health read over the late news and the later release from Sydney Water. It was suggested that the handling of the matter was a "shambles".

At 8:45am on Thursday 30 July, the Minister spoke to the Premier and agreed that an Inquiry should be held into how the contamination occurred and notification and management of the issue. The Premier announced the Inquiry later that day.

Early actions announced

As the media attention to the issue continued, the Minister directed his staff to draft a media release and organise a media conference for the afternoon. Its purpose was to explain the actions which were being taken in response to the levels detected. Both were essential if the incident was to receive a proper perspective without causing unnecessary alarm. At this point, Sydney Water was telling the Minister that the possible source of the contamination was water from the Upper Canal to the Prospect plant. The canal was to be closed and chlorine levels increased.

The Minister assumes responsibility

Around 4:30pm, Minister Knowles met with the Premier, the Minister for Health and officials of NSW Health and Sydney Water. Pollett advised the meeting that the likely source of the contamination was either at or before the Prospect plant possibly rainstorm contamination from the Upper Canal or backwashing of filters at the plant. He advanced the "slug" theory for contamination whereby intermittent pulses of contaminated water had been released into the Sydney distribution system, accounting for high levels on one occasion followed by low levels on subsequent occasions.

On hearing this, Reid recommended that the alert be extended forthwith to the Prospect system.

The recommendation was accepted by the Premier and the Ministers at the meeting.

The Premier then questioned what Sydney Water was going to do about the problem. I am told that Pollett stated that the water supply was now bypassing the Prospect plant. He said the Upper Canal (from the Upper Nepean dams to the plant) had been shut off and water for Sydney was being drawn and chlorinated only from Warragamba.

A media release was drafted at the meeting, extending the boil water alert to all Sydney residents served by Prospect. The words chosen were based on Pollett's advice. It stated:

"The Managing Director of Sydney Water, Mr Chris Pollett said tonight the outlet at the Prospect Water Treatment Plant has been shut off and water for Sydney was being drawn and disinfected from Warragamba dam so that the water to Sydney will completely bypass the Prospect Water Filtration Plant."

The release also referred to positive findings for both *Cryptosporidium* and *Giardia*.

This media release was wrong. The Prospect plant was not then, and has never been, bypassed.

During the meeting, high positive results from samples taken at Palm Beach the night before (365C/151G) were phoned through to Pollett. He advised the rest of the meeting. These results confirmed the understanding, at this stage, that the problem was across the Prospect system.

Sydney Water issued the media release drafted at that meeting at about 7:00pm that evening. Minister Knowles also

issued a similar release. The documents are in the appendices. The fact that the bypass was not carried out was not corrected until a further "clarifying" media release at 6:00pm the following day being Friday 31 July.

Friday 31 July

Misinformation by Sydney Water

In the late morning Minister Knowles announced the establishment of an Expert Panel to advise on the future quality of the water supply. The panel comprises experts in infectious diseases and microbiology as listed in the appendices. It became responsible for reviewing all test results as they became available and defining the criteria by which to decide when it was safe to drink Sydney water. The Minister also described the extensive testing being undertaken.

The media continued to maintain intense interest in the event. Pollett gave an interview to the ABC in which he repeated the suggestion that the Prospect plant was being bypassed.

During the morning Minister Knowles became aware that the Prospect plant was still operating and had not been bypassed. Initially this information came to him from AWS (the operator of the plant) through the Premier's Department. This was contrary to the advice he had received from Sydney Water the previous day. The Minister met later with Pollett and Sydney Water executives who confirmed that the plant was still operating.

Sydney Water explained that there had been operational difficulties in effecting a bypass and, when early morning samples taken at the outlet of the plant showed zero levels *Cryptosporidium* and *Giardia*, it was decided that it was not necessary to close down the plant. Sydney Water believed that the measures to close down the Upper Canal and isolate the Prospect plant were sufficient to prevent any further contamination entering the system.

Pollett has submitted to me that the media release of 30 July was accurate because it spoke of future events and the "media release does not mislead the public into believing steps had been taken." "This submission is contrary to the claim in the release that the outlet has been 'shut off" and must be rejected.

Pollett told me that he recalls speaking to the Minister early in the morning of 31 July and told him there had been a delay in completing the bypass but that it should be completed by mid morning. The Minister does not recall such a conversation and, as Pollett continued to tell the media that the Prospect plant was bypassed, it is impossible to accept Pollett's recollection.

The "clarifying" media release was issued by Sydney Water at 6:00 pm that evening, indicating that while a clear water tank had been isolated, the plant was continuing operations. The media statement says that Pollett stressed that the contamination did not originate within the plant, but most likely came from the Upper Canal.

The media release of 30 July was intended to allay public concern but was inaccurate. The failure to provide prompt and accurate advice to the Minister was a serious breach of trust. The Minister and the public were entitled to expect greater accuracy in the advice from Sydney Water.

Saturday 1 August

Process of lifting alert is agreed

Around 10:30am the Minister met with Sydney Water to discuss the testing regime and timing of results giving the "all clear" to various areas. There was confusion over whether fluoride could be used as a marker to assist in identifying whether the system had clean water.

At midday the Minister met with the Expert Panel and agreed on a process to be followed for testing and clearing the system. In a subsequent media conference, the Minister estimated that an all clear for all parts of the system might take six to eight days. The Minister tells me that he spoke to the Director-General NSW Health that evening about test results and areas proposed for release.

Sunday 2 August

The Expert Panel agreed to authorise Sutherland Shire to be announced as clear because it was no longer getting water from Prospect. The Minister announced the decision at 3:30pm.

Sydney Water identified the additional post code areas to be released from the boil water alert and sent these to Minister Knowles' Office around 9:00pm that night. The Minister sought confirmation from the Director-General of NSW Health who advised that the all clear could be given for the identified areas at 9:00am the next morning.

Monday 3 August

The Minister issued an early morning media release stating that another 50 suburbs were cleared from 9:00am. At 1:30pm the Minister met with the Premier and Sydney Water and NSW Health officials for an update on the testing and procedure for the rest of Sydney. At 3:30pm the Minister announced that a large area of western Sydney was cleared.

Tuesday 4 August

The Minister issued a media release announcing the all clear for Sydney and removal of the boil water notice.

Conclusions about the management of the incident by Sydney Water and NSW Health

The following is a summary of the conclusions which were detailed in the Second Interim report.

Sydney Water was not prepared for an event of this magnitude. The incident management procedures did not serve as an effective guide to the management of the event. The incident reporting chain in both NSW Health and Sydney Water appears to have failed to provide swift notification to an appropriate decision maker regarding the detection of very high levels of *Cryptosporidium* and *Giardia*.

There were a number of deficiencies in the procedures and management processes that were in place in relation to the issuing of health alerts at the time of the First Event. There was a failure to identify an appropriate procedure in advance, which vested authority in an appropriately qualified person to take responsibility for the issue of a health warning.

The process by which the public was advised of the extent of potential health problems was flawed. The Memorandum of Understanding between NSW Health and Sydney Water did not deliver effective communication between the two agencies.

There appears to have been poor communication between Sydney Water's operational team and its media team, despite the pivotal role of the latter in coming to an agreed position with NSW Health.

The effect of Sydney Water's decision, followed by the attempt to "kill" NSW Health's media release, was to cause confusion and delay in the issue of a confirmed warning for the whole of the Prospect system. Agreement to issue that warning was only given after the intervention of the Premier and other Ministers the following day.

The actions of the Government through the Premier and Minister Knowles in establishing an Expert Panel and Minister Knowles in accepting the responsibility of informing the public was essential.

Communications from the Managing Director to the Minister were poor in the lead up to the Sydney-wide boil alert and during the period that the Minister had effectively assumed responsibility for managing public knowledge of the event.

At the time of the First Event there was no protocol in place, either in NSW or in most developed countries, for the issue of a boiled water notice.

NSW Health does not currently possess the expertise necessary to make a fully informed decision about the impact of a potential contaminant in the water supply system on the Sydney population.

Inaccurate information provided to the community regarding the likely health impacts of *Giardia* was not corrected by NSW Health.

At the time, NSW Health had limited specific statutory powers in relation to the regulation of drinking water. It relied on the Memorandum of Understanding for its regulatory powers. The MOU provided no guidance as to who is to issue the health alerts or take rectification action in the event of a contamination incident.

Public confidence in the water quality will only be achieved:

- if information about water quality is published; and
- a transparent process for the issue of a health alert is determined.

Some of the problems indicate a lack of effective application of the incident management systems in place at the time. Others may have arisen from the Corporation's structure which required it to give equal consideration to its business objectives, protection of the environment and the protection of public health.

The correct decision?

I am satisfied that, from the material available by 7:30pm on the evening of 29 July, the interests of public health favoured a decision to issue an alert for the whole of the Prospect system. In the previous week, there had been contamination in the CBD which is part of the Prospect system with high and extremely high levels of *Cryptosporidium* and *Giardia*. Once the high levels were found in the Potts Hill reservoir, it was obvious that previous theories of localised contamination were no longer tenable. I accept that it was possible that, having regard to the open nature of the Potts Hill reservoir, contamination could enter the system at that point even though no source had been identified. There had been measurement of levels of contaminant in the sediment at the Prospect plant, which were assumed to be very high. This presented an obvious source of contamination. It was also known that the operation of the plant would have the potential to release water from the clear water tanks in pulses. This could explain the initial event, followed by clear readings and subsequent contamination of the system. It was also apparent that, because of the configuration of the system, contamination from the Prospect plant would be likely to be identified earliest in the city, and later only in the further reaches. Although it may have been possible to isolate the clear water tanks in the plant, this would not deal with the water which had already been released to the system.

In these circumstances, and particularly considering the high readings which had been previously measured, and the complete uncertainty about the cause, in my opinion, the decision which reflected appropriate concern for public health required that an alert be issued for the whole of the Prospect system. I accept the need to be careful about causing alarm and the risks to people when boiling water. However, the decision by Sydney Water to limit the alert appears to have been influenced by concerns for the reputation of the Corporation.

The effect of Sydney Water's decision, followed by the attempt to "kill" NSW Health's media release, was to cause confusion and delay in the issue of a confirmed warning for the whole of the Prospect system. Agreement to issue that warning was only given after the intervention of the Premier and other Ministers the following day.

Further evidence in relation to the First Event

Since providing the Second Interim Report, I have received a further account of the events from Metcalfe, Keelan, Hill and Mr Colin Ridley, Manager, Residential Retail.
Metcalfe tells me that he is concerned that the account of the events of 29 July might reflect adversely on his management skills. I did not intend this and confirm that any criticism which I made of the events of that evening does not include a criticism of Metcalfe.

Both Keelan and Ridley now tell me that the view of the operations room before Pollett arrived was that the boil water alert should be applied to the whole of the Prospect system. Ridley also gives an account of his conversation with Hill on the 23rd floor when he says he urged Hill to extend the boil water alert to the whole Prospect system.

His account of the conversation is as follows:

RIDLEY: "There was some discussion about the changes, yes. I put to David Hill that we couldn't not alert the northern suburbs of Sydney because they were fed by the Prospect system and, if we had contamination at Prospect, then everywhere that was fed from Prospect was suspect. He said, in reply to that, that we didn't have any positive results from the northern suburbs, to which I replied and I can't remember my exact words that we didn't have any results, positive or negative, from the northern suburbs, so we had to assume that they were affected.

I also expressed concern about the deleting of *Cryptosporidium*. He told me that Health said that crypto was not a problem. That was new to me, so I was a bit taken aback by that. This was new information for me. I also mentioned, at some point in that discussion, Arnott's and an example that we should take from them, in terms of alerting customers. Arnott's are often considered to be one of the examples of the company that did it well. David Hill told me that if he wanted my opinion he'd ask for it."

He was asked by Mr B Rayment QC who appeared for Hill.

QUESTION: "Did you tell him that you had contamination at Prospect and everything that was fed from Prospect was suspect?"

RIDLEY: "Yes, I did..."

Hill told me he had no recollection of this conversation. This is not surprising given the pressure of the events. I accept Ridley's account.

Further conclusions about the decision

Hill has recently made further submissions to me about the conclusions in the Second Interim Report with respect to his role in the decision about the extent of the health warning to be issued. Hill says he played no part in the decision made on 29 July and was lacking technical competence to define the areas of the alert. He was represented by Mr B Rayment QC who made detailed written and oral submissions. I was also asked to reconsider the relevant section of the Executive Summary in the Second Interim Report. Hill was also shown a draft of this chapter of the report and Mr Jonathan Simpkins of Counsel made submissions on his behalf.

In the Second Interim Report I considered the evidence which Pollett and Hill and the other senior employees of Sydney Water gave me about the making of the boil water alert decision and Pollett's conversation with Hill that evening. I concluded that "although Pollett may have made the actual decision, Hill defined its parameters."

Having reviewed the whole of the material available to the Inquiry and considered the further evidence of Hill and Ridley and the submissions made, I remain of my original view. It must be remembered that the debate in the operations room turned upon whether, because contamination had been identified at Prospect, the whole Prospect system should be the subject of a boil water alert or whether, because the positive readings were only for part of the system, the alert should be limited. In my view, although Hill may not have made it, he significantly influenced the decision to confine the alert to less than the whole Prospect system. It was that decision which was considered in the discussion on page 65 of the Second Interim Report and in the immediately preceding section of this Report. I am not persuaded that the Executive Summary requires amendment.

Management of the Second and Third Events

I have reviewed the management response to the Second and Third Events and conclude that the management problems experienced in the First Event were not repeated during the subsequent events. Similarly, the failures in communication between Sydney Water and NSW Health did not recur. Both organisations implemented appropriate protocols and managed the events effectively. NSW Health provided timely information to the public via press releases, media advice and its Internet site.

Chapter 5: Sources of contamination in the catchment

The raw water from the catchment contained elevated levels of *Cryptosporidium* during the time of the contamination events, especially the Second and Third Events. The turbidity of the catchment waters at these times also significantly increased, again especially during the Second and Third Events. Turbidity (the quantity of particles in a water sample) is a useful measure of water quality and often indicates the presence of contaminants such as faecal coliforms and bacteria, and sometimes *Cryptosporidium* and *Giardia*.

It is important to note from the graph on the following page showing *Cryptosporidium* counts in raw water that few results were collected prior to late July. Before the contamination was detected, a routine monitoring program which was in place involved infrequent sampling and testing of catchment waters. This makes it difficult to make a definitive conclusion on the relative contribution of raw water quality to the early stages of the First Event.

I am confident that contamination of the water from sources within the catchment was the most significant cause of the events.

My Third Interim Report reviewed the state of water quality in the hydrological catchment. It concluded that the catchment is seriously compromised by many possible sources of contamination, both of *Cryptosporidium* and *Giardia* and a wide variety of other pollutants. This is consistent with the findings by the Healthy Rivers Commission Inquiry and the EPA (HRC, 1998 and EPA, 1993). Maps showing Sydney's water supply catchments and potential sources of contamination are included in the appendicies.

Sources of contamination in the Inner Catchment include cattle grazing, residential development areas, native animals and feral animals. A map showing land tenures in the Inner Catchment is included in the appendices. The continuation of human and animal activity in the inner catchment is of concern, given its intended role as the natural filtration system for the wider catchment.

Activities in the Outer Catchment constitute a long-term source of contamination. It includes major cities, smaller urban centres, many small rural settlements and individual properties. These can produce significant pollution in the form of sewage and stormwater run-off that may enter the water supply. There are also significant cattle grazing and intensive agricultural developments. Urban growth and animal farming is projected to intensify in the Outer Catchment in the coming years. Without effective long term planning and management, there is serious doubt about the capacity of the catchment system to control the contamination loads contributed to the various tributaries and sub-catchments upstream of Warragamba dam.

The condition of the catchment, especially the Outer Catchment, and its planning and regulation requires immediate attention to control future developments and give priority to the protection of water quality. My Third Interim Report provided detailed recommendations on these matters and these are summarised in Chapter 2 of this report.

The focus of this Inquiry has been on possible sources of *Cryptosporidium* and *Giardia* in the catchment. These parasites are significant because they are indicators of faecal contamination, which can carry a wide range of contaminants of concern to human health. While *Cryptosporidium* and *Giardia* are important, they are but two of a wide variety of pathogens that can occur in polluted water. Also of concern are pesticides, nitrates and phosphorous which cause toxic algal blooms, industrial pollutants and even oil and grease deposited by cars on roads in the catchment.

Mining is a significant potential threat to catchment waters. In the Warragamba and Upper Nepean Special Areas, coal mining is undertaken. Six unworked coal mines remain unrehabilitated and there are a number of current shale, clay and sand extraction leases. In the outer catchment, coal mining and base metal mining could produce run-off which potentially poses a risk to water quality. The potential threat which mining poses is illustrated by the problems with peat extraction at Wingecarribee Swamp.

Numerous other development activities in the catchment contribute these additional pollutants which can compromise the natural purification processes for which water storage areas such Warragamba dam are designed.

What specific sources of the parasites are of concern?

The Inquiry has undertaken a preliminary investigation into the possible specific sources of *Cryptosporidium* and *Giardia* contamination related to the recent events and has reached some general conclusions. However, the state of knowledge about the catchment is not sufficiently advanced to allow definitive conclusions about the exact sources of the contamination. Further research and investigations are required. These are suggested in Chapter 16 in this Report.

Sewage treatment plants

Sewage treatment plants (STPs) are ranked as highest risk as a source of *Cryptosporidium* and *Giardia*, both in terms of potential parasite numbers and strains likely to be infectious to humans. STPs are of concern because they can release significant amounts of poorly treated effluent during periods of rainfall or plant failure. STPs are also a concern in relation to bacterial and viral pathogens that can be contained in human faecal matter.

Nine STPs are located in the Warragamba catchment, with one operated by Sydney Water and the remainder by local councils.

The EPA regulates sewage treatment plants by the issue of licences and other regulatory instruments under the pollution control legislation. The EPA conducts inspections of STPs, negotiates pollution reduction programs, conducts compliance audits and issues legal notices. Its enforcement powers include the issue of penalty infringement notices and prosecutions.

At Goulburn STP, during dry conditions, the treated effluent is pumped onto designated areas and does not go directly into the Wollondilly River. However, there are limited storage facilities for its partially treated effluent and no wet weather storage at the irrigation area. This means that during heavy rain, the irrigated effluent, including the partially treated effluent, can be washed into the Wollondilly River. The effluent management facilities are currently being upgraded in consultation with the EPA.

The other eight STPs Lithgow, Wallerawang, Bundanoon, Berrima, Bowral, Mittagong, Moss Vale and Mount Victoria discharge effluent directly into tributaries of Warragamba dam. The EPA advises me that the Lithgow STP has been performing relatively poorly and that it has been involved in extensive negotiations with the council to improve the plant's performance. The effluent from this plant, however, flows into Lake Lyell before entering the Coxs River. The Wallerawang STP also performs relatively poorly, although the discharge goes to Lake Wallace and Lake Lyell before entering the Coxs River.

Wingecarribee Shire Council is intending to upgrade the small STP at Bundanoon, which is performing satisfactorily. Council has no plans to upgrade the small Berrima plant, which is also reported to be performing well. The EPA has required council to upgrade the Bowral and Mittagong STPs by July 2001 and 2000 respectively. The Moss Vale STP was upgraded in 1995. Sydney Water has recently upgraded the Mt Victoria STP.

Discharges of poorly treated or untreated sewage from Mittagong, Bowral and Goulburn STPs occurred during the August rainfall events. There were power failures in Berrima, Bundanoon, Moss Vale, Bowral and Mittagong plants which all overflowed raw sewage into the Wingecarribee River in late August 1998. While all of these sewage inputs occurred far from Warragamba dam, computer modelling of storm water contaminated by the storm event, indicated that the travel time to the offtake at the dam wall was approximately one week.

In addition to these large STPs, there are several other 'package STPs' located throughout the catchment which aerobically treat wastewater for irrigation. These package plants are regularly used by businesses

such as service stations, for example, those located at Marulan and Penrose. The Marulan package STP has experienced some problems with run-off from its irrigation areas during wet weather. The EPA has recently required its irrigation system to be upgraded. There is also a package STP operating at Mt Piper Power Station.

The Inquiry has commissioned faecal coliform testing throughout the catchment. The highest level was found at the inlets downstream of the Nattai River, which carries effluent from the Mittagong and Moss Vale STPs, and Werri Berri Creek, which has septic seepage flowing into it from the unsewered area of The Oaks and Oakdale.

Sewer overflows

Sewer overflows occur at designed release points installed as part of the sewerage system to prevent wastewater from backing up in people's homes and properties. The ecological impacts of sewer overflows in receiving waters largely depends upon the total amount of contaminants discharged, their location in the river system and the frequency of occurrence. While wet weather overflows are generally less serious than dry weather overflows (caused predominantly by pipes being blocked by tree roots), during extended or heavy rain water can enter the system through illegal stormwater connections or seep through cracks in pipes.

Sewer overflows are not currently regulated, although a process of licensing sewer overflows in the Sydney Water operational area is under way. Sydney Water has prepared Environmental Impact Statements (EISs) for each of its sewerage systems as a basis for EPA licensing of the overflows. The intent of the EISs is to assess the environmental, recreational and public health impacts of the overflows and to propose management strategies and targets to be incorporated in the licences.

The licensing scheme will not cover sewer overflows outside Sydney Water's operational area. Nor is there any record kept of those overflows. However, it is likely that a significant number occurred in the catchment during the heavy rains.

On-site sewage management facilities

On-site sewage management facilities serve single residences in unsewered areas. The basic function of these systems is to treat all the wastewater produced by a household and distribute it to adjacent land. There is a broad range of on-site systems available, including septic tanks with associated absorption fields and composting toilets. Users of on-site systems in the catchment include:

- households in unsewered villages such as The Oaks and Oakdale in Wollondilly;
- rural residents such as the 40 homes of Darkes Forest;
- mining operations such as the various collieries that operate in the Upper Nepean Catchment;
- the many picnic areas that are often located near the dam facilities, such as the picnic areas adjacent to Cataract dam; and
- Sydney Water administrative offices, cottages and field huts.

Discussions with the councils that cover the catchment suggest that around 21,500 on-site systems occur in the catchment area.

The urbanised areas in the Warragamba inner catchment appear to present a significant risk to contamination of the water supply. As noted, the highest coliform values were observed at the inlets downstream of the Nattai River, which carries effluent from the Mittagong and Moss Vale STPs and Werri Berri Creek, from which unsewered villages have direct drainage.

The unsewered villages of The Oaks and Oakdale, located west of Camden, have been identified as major risks of faecal contamination from septic tanks. This situation has been of particular concern as the area is located only eight kilometres from the Warragamba dam wall. In response to this, an accelerated program for sewering the villages of The Oaks and Oakdale has been approved by the Minister for Urban Affairs and Planning, to commence in 1999. At this stage, the Government has

allocated $871,000 to Sydney Water to develop the design options for the treatment works and to commence the EIS process, including community consultation. Other unsewered urban areas are located at Taralga, Tarago, Hartley, Yerrinbool, Nattai Village, Yerranderrie Village, Sutton Forest and Kangaloon.

Regulation of on-site septic systems is the responsibility of local councils. In response to concern that some on-site systems were failing to satisfy environmental and health performance criteria, the NSW Government recently released a package of reforms aimed at improving the performance of these systems. The reforms consist of a new set of environment and health protection guidelines as well as amendments to the Local Government (Approvals) Regulation 1998. The objective of the reforms is to put in place a sound framework for ecologically sustainable on-site sewage management practices and regulatory strategies. The package includes measures to provide local councils with more accurate figures on the number of on-site systems operating in their areas.

Agriculture

Numerous agricultural activities are undertaken in the catchment, including sheep and cattle grazing, poultry farms, chicken hatcheries and piggeries, dairies, saleyards and abattoirs.

Cattle grazing, including along unfenced riverbanks, occurs extensively throughout the catchment with a large concentration in the Wollondilly catchment. During the recent heavy rainfall events, it is likely that run-off of animal manure and soil loads would have occurred from grazing lands denuded of pasture by 3-6 years of drought and from river banks subject to removal of riparian vegetation. The protection that riparian vegetation offers is crucial to water quality as it acts as a buffer zone in deterring livestock from walking in waterways and stabilises the riverbank area.

Cattle faecal matter has been found to protect oocysts which makes it likely that run-off from agricultural land could be a significant source of *Cryptosporidium* (Le Chevallier et al, 1998). Some seasonality has been noted in the number of oocysts in the environment and this has generally been associated with calving/lambing incidence. Calves and lambs are known to produce prolific numbers of oocysts, with as many as 10 million oocysts per gram of faeces being excreted from infected calves (Fayer et al, 1997). While oocysts produced by cattle may be less likely to be dangerous to human health than oocysts sourced from human effluent, waterborne outbreaks of disease have been reported from these sources, particularly in the United Kingdom and New Zealand (Shianna et al, 1998).

Dairy farms are concentrated around the Wingecarribee local government area. Animal pollution from these farms mainly consists of run-off from milking sheds and pens, and may be exacerbated by wet weather conditions, especially if pen bunding is poorly implemented or non-existent.

The EPA regulates a number of the larger agricultural activities in the catchment by the issue of licences and other regulatory instruments. It also periodically inspects potential sources of pollution that may not hold an EPA licence. Generally these facilities are regulated by local councils. Non-mandatory guidelines are issued by NSW Agriculture.

The Goulburn Livestock Saleyards have no effluent or manure collection facilities in place and discharges occur in wet weather to the Wollondilly River, which is one kilometre from the Saleyards. An EPA notice has been issued to the council requiring it to install further facilities by the end of 2000. Livestock selling yards are also located at Moss Vale and Taralga. There is also a wool scouring operation and an abattoir at Goulburn.

Intensive horticulture using animal manure as fertiliser is also undertaken, for example, the orchards in the Upper Cordeaux, the flower and vegetable gardens around Werri Berri and potato growing around Kangaloon and Robertson.

Agricultural activities can contribute to water pollution, not only by the production of animal and chemical contaminants, but also by disturbance of vegetation near waterways. Such disturbance removes the natural barriers to pollutants entering waterways. The Department of Land and Water Conservation is responsible for regulating vegetation clearance that may be associated with agricultural

activities. The Native Vegetation Conservation Act 1998 prevents inappropriate clearing through the use of licences to clear vegetation and provides for the protection of "State Protected Land" which includes steep mapped land, land near prescribed streams and environmentally sensitive land. The Rivers and Foreshores Improvement Act 1948 requires a permit to excavate or remove material in, or within 40 metres of the bank or shore of a river, lake or estuary.

Biosolids

Sewage treatment requires the removal of solids to provide a clear effluent of suitable quality for discharge to the environment. These wastewater solids can be further processed to produce biosolids which contain useful amounts of plant nutrient and organic matter.

There are four options for the disposal of biosolids:

- disposal to receiving waters;
- disposal to the air through incineration;
- disposal to dedicated landfill; or
- processing to provide a useful organic soil conditioner.

Sydney Water has settled on the last option and in 1997/98 processed enough sewage to provide 173,466 tonnes of product to the following markets:

- agriculture 117,220 tonnes;
- horticulture/landscaping 43,175 tonnes;
- forestry 3,280 tonnes;
- land rehabilitation 9,020 tonnes;
- research 30 tonnes; and
- landfill 741 tonnes.

The sludge may be composted, although the majority used is treated with lime and given up to 20 days retention time in an anaerobic digester at 30 degrees Celsius. This treatment is considered sufficient to kill pathogens and other harmful organisms.

While most of the pathogens are killed, research has shown that *Giardia* cysts are still capable of detection in biosolids for up to six months and at high levels (McInnes et al, 1997). *Cryptosporidium* oocysts survive better than *Giardia* cysts and therefore are likely to be detectable for an even longer period of time.

Sydney suffered a significant outbreak of cryptosporidiosis in late 1997 and early 1998 and its sewage is likely to have been heavily contaminated with the pathogen. Furthermore, background levels of *Giardia* are always present in sewage, so large numbers of both organisms would be expected in biosolids produced during this time.

Investigations of biosolid application in the Warragamba catchment has revealed that a total of 5,378 tonnes was applied during 1997/98. A total of 5,328 tonnes was applied to three grazing properties and 50 tonnes to the degraded Woodlawn mining site. All of these applications were subject to EPA licences and met their conditions. However, these conditions do not include any criteria for *Cryptosporidium* and *Giardia*.
Sydney Water and NSW Agriculture have undertaken research which shows that biosolids improve infiltration of water into the soil and reduce erosion. Close monitoring of water quality downstream of large biosolid applications has not shown any deterioration in water quality, however this research was limited to faecal coliforms and Eschrichia coli and did not include testing for the pathogens. Further research is proposed.

While Sydney Water may be correct, the levels of *Giardia* identified in biosolids by other studies provide a significant reservoir of inactive pathogens that could be released by rain and washed into watercourses and reservoirs. *Giardia* concentrations of 640 cysts (Soares et al 1992), 2,000-5,000 cysts

(Thiriat et al, 1996) and 38,000-140,000 cysts (Gibbs et al, 1995) have been found in one gram (dry weight) of anaerobically treated biosolids. This has the potential to provide a vast reservoir of inactive parasites capable of recording positive results if released by rain and washed into the Warragamba dam.

This could explain the extremely high numbers of *Cryptosporidium* and *Giardia*, but the lack of illness in the community, during the Sydney events. This could also explain the low level of faecal indicator bacteria as they would have been destroyed by the treatment of the sludge. Sydney Water is commissioning further work to test the persistence of *Cryptosporidium* and *Giardia* in biosolids.

Stormwater run-off

As well as sewerage systems which take wastes from homes and businesses, there is a separate drainage system that carries away excess water from gardens, roads, footpaths and roofs of buildings in urbanised areas. Stormwater, or urban run-off, refers to the rain run-off from all sources. In most cities and suburbs, there are roadside drainage pits where rainwater run-off can enter the underground stormwater drainage system.

Most drainage water flows directly into waterways, causing pollution. In some cases, stormwater run-off can be more toxic than treated sewage released from STPs. The pollution contained in urban stormwater can include: sediment from development and new construction; oil, grease and toxic material left on roads by cars, such as lead, zinc and copper; nutrients and pesticides from lawn management and gardening; and viruses and bacteria from failing septic systems. The faeces of domesticated animals such as dogs may also be a major source of pollutants in stormwater, and also a potential source of *Cryptosporidium* and *Giardia*. Sewer overflows may also be picked up and transported by stormwater.

Responsibility for the management of stormwater is fragmented between State and local government bodies. Stormwater systems in the catchment are primarily managed by local councils. The EPA has recently developed a policy framework and best practice guidelines requiring councils to develop stormwater management plans.

Native and feral animals

Feral deer, pigs, goats, wild dogs, feral cats, foxes, horses and cattle infest parts of the catchment. Studies are being done to see if they carry human-infective *Cryptosporidium* and *Giardia*, but no conclusive results are available. Nonetheless, such animals are all potential carriers of these parasites, as are native animals such as kangaroos, wallabies, possums and koalas (Gasser and Morgan, 1998).

The National Parks and Wildlife Service has responsibility for feral animal control on the national park estate. It is also involved in joint control programs with Sydney Water in Inner Catchment lands. It is difficult to assess either the number of feral animals in the catchment or the effectiveness of control programs.

Little information is available to assess the number of native species to determine whether there has been any significant variation in numbers leading up to the contamination event. However, large numbers of kangaroos have been reported around the foreshores of Lake Burragorang as a result of the recent drought.

Other sources

There are a number of other sources of faecal contamination that pose a threat to the catchment. These include:

- public toilets located at recreation facilities on the river system, for example, at Avon, Cataract, Cordeaux and Nepean dams which are visited by approximately 1,000,000 people annually;

- illegal fishing in Lake Burragorang and Cataract;
- possible accumulation of *Cryptosporidium* and *Giardia* in sediments in Lake Burragorang; and
- swimming pool and water treatment plant discharges, both of which can contain concentrated sources of *Cryptosporidium* and *Giardia* swimming pools are located at Nattai, Wollondilly and Coxs River (EPA, 1993).

Conclusions on possible sources of *Cryptosporidium* and *Giardia*

It is clear that contamination of raw water entering the Prospect plant was a major cause of the recent events, especially the Second and Third Events. The state of the catchment poses continuing serious risks for the safety of Sydney's drinking water.

The lack of data about the catchment and the current monitoring regimes makes it impossible to be definitive about the specific sources of the *Cryptosporidium* and *Giardia* which contaminated the raw water in July - September 1998. However, a joint working group comprising Sydney Water and Australian Water Services staff has ranked the sources of risk in the catchment that pose the greatest threat of contamination by *Cryptosporidium* and *Giardia* at levels which threaten public health (AWT, 1998a). The results of this work indicate that the highest risk sources are sewage treatment plants, unsewered and sewered urban areas near Warragamba Dam and grazing in areas near the Dam. Of the 13 point sources identified, the top 8 (representing 23 individual discharge points) relate to sewage treatment plants.

All of the sources listed above are ongoing threats to water quality and require urgent attention. Further research is required to create an accurate picture of the catchment's health. This work will need to analyse the risk posed by possible sources of contamination and review the following:

- magnitude of contamination;
- frequency of the discharge (continuous vs run-off related);
- type of contamination (animal or human); and
- distance from the lake and travel times during events.

Further information on possible sources

The Inquiry commissioned tests to try to identify whether the source of the *Cryptosporidium* and *Giardia* contamination was human or animal, in an attempt to determine in the recent contamination events.

The tests indicated predominantly herbivore faecal contamination in the dams, but also provided strong evidence of occasional human faecal contamination. It can be concluded that the bulk of the *Cryptosporidium* and *Giardia* detected was most likely to have come from catchment animals.

Verification tests were subsequently attempted (both in Australia and the UK) to attempt to confirm whether the *Cryptosporidium* was of human or animal origin. These tests were unsuccessful. This may have been because many of the *Cryptosporidium* seen were empty shells.

High numbers of parasites in raw water would normally have been associated with other faecal indicator microorganisms. However, consistently low numbers of faecal indicator bacteria in the raw water were reported by AWT during the Events. A possible explanation is that the source of the faecal material was so old that the indicator bacteria had died out, although the *Cryptosporidium* and *Giardia*, which are very resilient, were still detectable. The low levels of faecal sterols measured supports the possibility of a distant source of faecal contamination and the lack of infectivity would support this view.

These findings suggest significant contribution to the recent Events was faeces from animals. This would have accumulated on the land over a period of time in the drought and washed into the watercourses during the unusually heavy rainfalls.

This does not mean that other sources can be disregarded. Other possible sources of faecal contamination, such as overflowing STPs and unsewered areas very close to the dam, are likely to have contributed pathogens to the raw water stream in the recent contamination Events. These, and sources of other pollutants such as mines and industrial sites, are ongoing threats to the protection of water quality in the catchment.

Chapter 6: The cause of the Events

What caused the contamination events?

The First Interim Report identified a number of possible causes of the first contamination event. The Second Interim Report provided an update and commented on causes surrounding the Second Event. The Third Interim Report contained a detailed assessment of the catchment and possible sources of contamination. It also examined the performance of Sydney's filtration plants.

During the course of the Inquiry all available expertise in catchment management, limology, hydrology, treatment and science has been applied to identifying possible causes. Much has been learnt but some matters can still not be fully explained.

There is general agreement on some aspects of the cause of the events but strong disagreement on others. This chapter traces the water system, from source to tap, examines the possible causes identified in each element of the system and discusses their possible impact on the three contamination events.

Catchment

There is general agreement that the catchment is compromised. The possible sources of the parasites are outlined in detail in the previous chapter. They include:

- sewage treatment plants (STPs);
- sewer overflows;
- septic systems;
- domestic animals;
- biosolids;
- stormwater run-off; and
- native and feral animals.

It is also clear that the sources of the parasites were both human and animal waste. Their transportation in the raw water through the system was the primary factor in all the Events.

Climate

Climate can have a considerable impact on the presence of the organisms. The drought over recent years meant there was limited mobilisation of *Cryptosporidium* and *Giardia* from the potential sources within the catchment. It would have resulted in a substantial build up of contaminated material on river banks and in streams. This large reservoir of *Cryptosporidium* and *Giardia* once mobilised would have been a major contributor to contamination within the system during the three Events.

Rainfall events

In normal circumstances, most of the potential contaminant load within the catchment does not enter watercourses. Contaminants are contained and treated in STPs or lie dormant on land. The small amounts which enter the water courses and dams mostly settle to the bottom or are removed in the filtration processes at the Prospect plant.

However rain events can mobilise the *Cryptosporidium* and *Giardia* particles and introduce them to water courses. At times of heavy rain STPs are more likely to overflow, septic tanks to overfill, and runoff from agricultural land and unsewered urban areas to increase. If the levels of *Cryptosporidium* and *Giardia* entering water courses are high and the inflows into the dams are large, there may be limited time for the particles to settle and treatment plants may not be able to remove all of them.

Intense rainfall can have a significant effect on raw water quality, particularly after periods of drought. Rainfall and/or snow melts have been a consistent contributor to most overseas contamination incidents. During these events contaminated material is swept into streams, rivers and storage facilities.

Some of the rainfalls in the Warragamba catchment during the recent Events are set out in the following table.

Table 1: Rainfall in Sydney's catchments during the contamination events (in millimetres)

Date	Bowral	Camden	Katoomba	Wollongong
03.06.98	15.2	7.0	28.0	6.0
04.06.98	2.2	6.0	24.0	31.0
23.06.98	50.4	49.0	49.0	Nil
21.07.98	28.0	17.0	19.0	Nil
07.08.98	25.6	25.0	39.0	40.6
08.08.98	114.8	62.0	159.0	136.4
16.08.98	21.8	44.0	39.8	79.6
17.08.98	39.2	58.0	44.2	32.0
18.08.98	60.8	50.0	17.2	316.0
19.08.98	34.6	4.0	1.0	99.0

Both the 23 June and 21 July rain events, which were the first heavy real rain since July 1997, resulted in increased flows into Warragamba dam and increased water levels within the dam.

The heavy rainfall in August also caused overloading of the sewage treatment plants at Goulburn, Bowral, Mittagong, Bundanoon and Berrima, in the catchment. The Goulburn plant was unable to irrigate its treated effluent which was released into the Wollondilly River. Sludge ponds at Bowral were flushed into the river and the Bowral, Mittagong, Bundanoon and Berrima plants were all required to operate at extraordinary levels. The consequence was that significant volumes of poorly treated sewage were released into the Wollondilly River and entered the dam.

There is also evidence of the introduction of contaminated material into the Coxs River. The Wollondilly and Coxs River together comprise in excess of 60% of the flow into Warragamba dam.

There is little doubt that the inflow from the rain events was heavily contaminated.

Dams

Water storages, such as Warragamba dam, can operate to naturally remove *Cryptosporidium* and *Giardia* before water enters treatment plants. If water is stored for extended periods, parasites may die off or be locked into sediment as they settle on the dam bed. Poorly managed storages, however, can create conditions in which oocysts and cysts cluster at certain temperature zones within the dam. Concentrations of the parasites can then be rapidly transported and fed into the intake point of the treatment plant, presenting it with a slug of highly contaminated water.

The rain in June and July resulted in the Warragamba dam receiving 16,750 megalitres (ML) of water and rising 0.22 metres. The rainfall in August resulted in flood peaks and high inflows which dramatically increased water levels and caused the dam to spill.

The dam filled in two very fast steps. Following two days of heavy rainfall, from 7-9 August, it went from 58% to 83% full. Two weeks later, following two more days of heavy rain on 16-18 August, it went from 83% to 100% full. This type of rapid filling has never occurred in the history of the dam and is estimated to be a one in thirty year event.

Large areas of the foreshore (1,800 hectares) of the dam were re-flooded during these events. This would undoubtedly have mobilised a large volume of faecal matter which had been deposited on the foreshore of the dam by native, feral and domestic animals defecating at the water's edge over a period of more than six years, since the dam was last full in 1992. This material had the potential to carry very large numbers of *Cryptosporidium* and *Giardia* into the water of the dam.

Samples taken on Wednesday 26 August revealed high levels of contamination in the dam at various depths. Subsequent studies have examined the likely flows of contaminated water within the dam. This is largely determined by water temperature and wind. These create density differences through the water column which separate and partition matter within the dam. These studies demonstrated that a sharp temperature gradient known as a thermocline was operating which resulted in different layers of water density. Both the thermocline and the cold water immediately below it were found to contain high levels of *Cryptosporidium* and *Giardia*.

Wind and temperature changes within the waters of the dam generate internal waves at the level of the thermocline. The intermittent level of measured contamination may be explained by these waves causing the thermocline to periodically rise and fall through the depths at which water was being extracted to feed the Prospect plant. This is clearly demonstrated in the figure below which compares water temperature in the Warragamba pipeline and positive tests in the raw water during August. When warmer water was extracted from above the thermocline, almost no positives were recorded. *Cryptosporidium* has been found to survive more readily in colder water.

The concentration of contamination within the dam had the potential to feed slugs of contaminated water to the plant during all three Events.

Upper Canal and Warragamba pipelines

The Upper Canal brings raw water from the Upper Nepean dams to the Prospect plant. The Warragamba pipelines bring raw water from Warragamba dam to the plant. A number of possible causes of contamination were identified within these elements of the system.

Dead dogs and foxes found in the Upper Canal

The catchment is regularly patrolled and dead animals are found from time to time. They are a potential source of contamination of the raw water entering the Prospect plant. I am informed that some dead animals were removed from the Canal during the First Event and these tested negative for *Cryptosporidium* and *Giardia*. I do not believe they played any part in the contamination events.

Environmental flush of the Nepean River

On 7 July the Nepean River was scoured during an environmental flow test and the waters discharged into the Upper Canal and the Prospect plant. The flow rate in the river was increased for several hours and then reduced again. Because of concern about the low storage level, this flow was taken into the Upper Canal rather than allowing it to spill from the weir and proceed downstream. The flow in the Canal increased from an estimated 100 ML/day to approximately 400 ML/day. This significantly increased the scouring of material from the bottom and sides of the river and the Canal and fed it into the Prospect plant. If *Cryptosporidium* and *Giardia* were present, they would have been washed into the plant.

The turbidity of the treated water at the plant did increase slightly suggesting increased passage of particles. I am satisfied that this incident is likely to have contributed some *Cryptosporidium* and *Giardia* organisms to the system, but the timing and magnitude is not such that it could be the sole cause of the high levels found from 22 July.

Raw water turbidity events in the canal and pipelines

I am satisfied that the breaking of the drought and subsequent significant rainfalls resulted in increased runoff of contaminated material into the dam.

This is reflected in turbidity levels in the raw water that was supplied to the Prospect plant. Raw water turbidity increased substantially at the Prospect plant on a number of occasions during July, August and September.

Turbidity is a measure of the "cloudiness" of water and does not alone indicate the presence or absence of *Cryptosporidium* and *Giardia* although it may indicate the presence of organisms. The figure following page 95 outlines the correlation between raw water turbidity and positive test results during the three events. The relationship between elevated turbidity readings and the presence of *Cryptosporidium* and *Giardia* is apparent.

There is general agreement that the Warragamba pipeline and Upper Canal received water with significantly increased turbidity during the three Events and that it contained *Cryptosporidium* and *Giardia*. Both AWT and AWS recorded positive findings - thousands per hundred litres in the samples of raw water being provided to Prospect.

Operation of the Prospect plant

There are a number of possible contributing factors within the Prospect plant. They include:

- release of sediment deposits from the inlet chamber during flow surges;
- loss of dilution water, reducing the effectiveness of the coagulation process;
- problems in the backwash procedure;
- cleaning of the clear water tanks and the use of a bypass channel;
- operational practices (including maximising filter runs and lower chemical dosing); and
- spikes of increased pH which may weaken flocs which trap the parasites in the filter.

Release of sediment deposits from the inlet chamber during flow surges

The inlet chamber takes the raw water to the chemical feeding and filtration facilities (a diagram of Prospect plant is included in the appendices). Inspection by divers revealed that approximately 2/3 of the floor of that chamber was covered with sediment washed in from the source canal. The sediment was from 20 to 1,000 milimetres deep and supported a healthy growth of aquatic weeds. If *Cryptosporidium* and *Giardia* were present in the sediment they could have been drawn into the plant during flow surges.

Loss of dilution water, reducing the effectiveness of the coagulation process

There were four instances in July when the coagulation process was not operating in an optimal mode because the dilution water pumps had stopped or the flow was interrupted for some reason. Loss of dilution water will lessen the effectiveness of the coagulation process. This could allow passage of particles the size of *Cryptosporidium* and *Giardia* through the filters and into the reticulation system. During these four instances there was a rise in the filtered water turbidity level indicated that an increased number of particles were passing through the plant and into the system.

Problems in the backwash procedure

Until 29 July, the water which had been backwashed from the filters had been treated and returned to the inlet of the plant. If the organisms were present in the influent water and trapped in the filters, they would have been present in the backwash water. If they were not removed in the treatment process (settling in the thickeners) they would have been fed back into the plant and could contribute to the contamination. Water that came from the centrifuge (which is used to concentrate the sludge taken from the thickeners) was also put into the inlet of the plant after passing through the thickeners and could have contained organisms.

Cleaning of clear water tanks and the use of a bypass channel

The clear water tanks balance the flows between the plant and the distribution system and at times allow sedimentation and become repositories for sediments which may contain *Cryptosporidium* and *Giardia*. During the course of the incident, both the tanks were taken off line sequentially for their first maintenance since the plant commenced operation.

On July 21 and 22, two incidents occurred relating to the cleaning of the two tanks. Both of these incidents resulted in an increase in the turbidity of the water leaving the tanks after filtration.

On July 21, the filtered and finished water turbidity increased. Plant operations personnel indicated that the levels in the tanks were being lowered to facilitate cleaning of the tanks. Their goal was to reduce the level in the tanks to 30% of capacity and then isolate tank Number 1. In fact the level lowered to approximately 24% before the process was reversed. The dilution water pumps for the coagulant chemical will not operate below the 27% level in the tank, and as a result the efficiency of the coagulation was reduced. This, in turn, reduced coagulation effectiveness and impacted upon the ability of the filters to remove particles. Individual filter data indicates that turbidity levels also increased. In response to this problem, the flow into the plant was increased rapidly to raise the level in the tank, increasing the filtration rate during a time when the coagulation process was not operating in an optimal mode. The turbidity in the treated water leaving the tank increased significantly from 9am until midnight when it returned to its original level. The increased levels were nevertheless within the agreed specifications for the plant.

The loss of dilution water and the attempt on 21 July to take a clear water tank off line had the potential to reduce the efficiency of the plant and provide an opportunity for the parasites to pass through the filters. In addition the ramp up of the system on 21 July had the potential to disturb any organisms contained in the sediment in the tanks which later tested positive in a significant concentration in one test. AWS disputes the legitimacy of the test.

The second incident involving the clear water tank occurred on 22 July when the tank levels were again lowered and a bypass channel between the clear water tanks, which could have become a repository for sediments containing parasites, was used for the first time. There is a possibility that this may have released material. During this incident the finished water turbidity increased but remained within specification.

The 21 July and 22 July events correlate with the high levels of organisms found in East Sydney on 24 and 25 July.

A sample taken on 29 July of the water of the online clear water tank provided a high reading. AWS questioned the technique used to procure this sample. Tests in the sediment of tank Number 2 taken on 5 August also showed positive readings.

Operational practices

During July, the Prospect plant was geared to operate economically although it performed well within specifications. This included long filter runs of up to 70 hours to conserve energy and backwash treatment and the lowest coagulant doses necessary to achieve targeted turbidity. These regimes, coupled with the maintenance operations, could have contributed to the passage of *Cryptosporidium* and *Giardia* during the First Event.

Long filter runs can allow *Cryptosporidium* and *Giardia* to pass through as particles build up on the filters and can eventually be "pushed through" as the filter becomes full of particles of any one size. Low coagulant doses may mean that coagulation can be sub-optimal and, when this happens, filtration becomes less efficient as fewer of the smaller particles stick together to form large clumps.

pH variation

AWT has recently submitted evidence that suggests that there were spikes in the pH levels due to changes in raw water quality and this may have affected the ability of the plant to coagulate *Cryptosporidium* and *Giardia* although not having a major effect on the other particles. The evidence is preliminary but it could explain the plant allowing *Cryptosporidium* and *Giardia* to pass when the quality of the treated water was otherwise satisfactory. AWS argues that there is no evidence to support the theory and that AWT does not fully understand the chemical process used at Prospect. This issue is important and should be tested further using the prototype plant.

Conclusions on the plant

AWS has claimed that none of the operational events that occurred in July 1998 could have caused the high levels of contamination reported in the First Event in the distribution system, unless implausibly high *Cryptosporidium* and *Giardia* concentrations were present in the raw water at that time. AWS argues that the filters were providing effective removal of turbidity and microbial contamination. It points out that there is no evidence of failure at the plant and that none of the Events, either together or separately, could explain the extraordinarily high levels measured in the distribution system in the First Event.

AWS further claim that the tank cleaning operations did not result in the discharge of sediment from clear water tank Number 1 at levels that would present a health risk. AWS submit that the Prospect plant was operated in compliance with the stringent standards of the US Interim Enhanced Surface Water Treatment Rule in relation to turbidity.

With regard to the Second and Third Events, AWS argues that the increased operating regimes introduced at the plant after the First Event resulted in very low turbidity and particle counts. They also point to the operation of the prototype plant and the very high log removal achieved.
Sydney Water argues that the plant allowed pathogens to pass and suggests variations in pH as a possible explanation for plant break through. They suggest that the use of dead organisms may explain the high log removal in the prototype plant.

I am satisfied that the *Cryptosporidium* and *Giardia* found in the distribution system during the events came through the Prospect plant. It must have been present in the catchment and passed into the plant, probably in turbid waters following rain and, in the case of the First Event, the flushing of the Upper Canal. The plant operated at various times in other than its normal manner, and filtration was less than optimum, at times, during the First Event.

I am satisfied this would have allowed some parasites to pass through the plant. It is also possible that some parasites were stored within the plant and released during the operational difficulties encountered in the First Event. However, the doubts regarding the accuracy of the test results makes it impossible to determine the levels of contamination which actually occurred.

Distribution system

Accumulation of organisms within the distribution system

In the time leading up to the First Event, low numbers of *Cryptosporidium* and *Giardia* could have been passing through the plant and accumulating in biofilms in the pipes and in sediments in the hydrants and mains. The accepted view is that *Cryptosporidium* and *Giardia* may persist in water for several months. The high number of positive results from samples taken during hydrant flushing

supports the suggestion that they may accumulate within biofilms or sediments. The figure below indicates the impact of hydrant testing on the overall results.

Sydney Water has not had a regular program of flushing the distribution system due, it states, to the drought conditions over the last four to five years. The absence of periodic flushing may have encouraged the build-up of deposits. The need for regular flushing as part of an asset maintenance program is discussed further in Chapter 14.

I have received various submissions which suggest that *Cryptosporidium* and *Giardia* may not accumulate in the distribution system. One submission from Dr Giovanni Widmer, Tufts University, USA, also suggested that some human strains of *Cryptosporidium* may not survive for long periods in water.

Sydney Water has also made a detailed submission to me arguing that the contamination did not originate from the biofilm and/or sediments in its pipelines. Its arguments included the following:

- a very large number of samples showed *Cryptosporidium* and *Giardia* from places which had not been flushed;
- once it was realised that contaminated water had come through the Prospect plant, Sydney Water was able to accurately predict when it would reach certain suburbs, indicating that it had travelled through the pipes; and
- international experts have stated that biofilms have not been demonstrated to concentrate oocysts and cysts to any great extent.

In my opinion, the correlation between the high readings for *Cryptosporidium* and *Giardia* and sampling at water hydrants is such that it must be accepted that some *Cryptosporidium* and *Giardia* had accumulated in the system and was released by flushing.

I am satisfied that these readings may be explained either by an accumulation of organisms in the biofilm in the pipes or in the sediments in the hydrants. The organisms probably accumulated relatively recently and must have passed through the Prospect plant.

As this report goes to press, I have been informed of work which has been done to investigate biofilm at Ramsgate. A pipe was swabbed to remove sediments and biofilm and water samples taken during the process proved positive for *Cryptosporidium* and *Giardia*. The results are a further indication of the likelihood of *Cryptosporidium* and *Giardia* accumulating in the biofilms and sediments although the organisms are probably inactive.

A localised contamination event in the Eastern CBD.

The initial test results in the eastern CBD convinced Sydney Water that they were facing a local contamination event. These results were obtained in areas around and close to the Central Business District. The hypotheses suggested to explain the results included:

- cross connection between sewer and water pipes in Sydney Hospital;
- pressure drop in the reticulation system causing a backflow from contaminated water from and to a source outside the water system;
- a broken water main in Crown Street;
- construction work on the Eastern Distributor and/or the new swimming pool in Hyde Park causing breakages in water and sewer pipes with cross contamination; and
- flushing of the distribution system, particularly at fire hydrants following identification of the initial levels, may have disturbed or concentrated material in the system.

Another possibility during the First Event was that the contamination entered through the uncovered Potts Hill reservoir. There is no evidence to support this theory and the test results showing *Cryptosporidium* and *Giardia* at the Prospect plant suggest it can be disregarded.

I am also satisfied that the Events were not caused by the ingress of contaminated water downstream from the treatment plant. It was suggested early in the Inquiry that bats in the pipeline from Prospect Reservoir to the junction chamber downstream from Prospect plant may have been a source of contamination. The test results showed *Cryptosporidium* and *Giardia* in water as it was leaving the plant and before it entered the tunnel and I believe his theory cannot be supported.

I do not believe that the available evidence supports either the cross contamination or ingress theories. The contamination was widespread throughout the system. However, as I have indicated, the consistently high readings following hydrant flushing are consistent with the view that *Cryptosporidium* and *Giardia* were present in the biofilm and sediments which were mobilised by the increased flows.

Test Results

In considering the possible causes, it is important to bear in mind the concern about the reliability of the test results due to difficulties in detection of parasites and deficiencies in the laboratory methods (discussed in detail in Chapter 8). Although the precise levels reported may not be reliable, a group of international experts commissioned by the Inquiry concluded that there was "unequivocal presence of *Cryptosporidium* and *Giardia* in Sydney's treated water at concentrations that are of public health concern".

Both AWT and AWS found high levels of the organisms in the raw water entering the plant but AWS found only very low levels in treated water. AWS argue that the AWT results are unreliable and probably caused by mis-identifying algae, which can mimic *Cryptosporidium* and *Giardia*. AWT argue that their tests are much more sensitive and that quality control testing indicate recoveries in excess of 50% in 47% of cases. This is at least three to four times higher than other testing methods. Testing by overseas laboratories has indicated the presence of the organisms although generally at a lower level.

Extremely high levels of *Cryptosporidium* and *Giardia* were reported from Prospect treated water on 4 September (500C / 3500G). Positive readings were recorded in the treated water over the next few days. AWT has expressed the view that the numbers of *Cryptosporidium* and *Giardia* reported on 4 September are not accurate and believe that the sampling point may have been contaminated. AWT maintains that the results from other samples of treated water are reliable. However AWS, has submitted to me that all of the AWT results are unreliable and cited the results of the AWT audit in support of their case.

Conclusions on cause

There is general agreement that the catchment is compromised and that there are multiple sources of *Cryptosporidium* and *Giardia* within it. This contributed to all of the contamination events.

There is also agreement that a combination of the drought and significant rainfall in July and August during all events mobilised pathogens in the catchment and transported them to the Warragamba and Cataract dams. Some scientists doubt whether the June/July rainfall was sufficient to cause contamination. In my view it probably was. Although minor in terms of rainfall, because it was the first event following the drought, it would have been likely to have carried a very high level of pathogens. Contamination of the dams was one of the most significant factors present during all three Events.

Clearly, significant contaminated material entered the dam and settled in a layer in or just below the thermocline. Internal waves along the thermocline intermittently passed contaminated material across the offtakes. This resulted in slugs of contaminated water entering the Warragamba pipeline and challenging the Prospect plant.

Testing by both AWT and AWS recorded high levels of *Cryptosporidium* and *Giardia* in raw water entering the plant during the Second and Third Events. They were accompanied by slugs of highly turbid, colder water. There was insufficient testing of the raw water during the First Event to allow a similar assessment.

During the First Event the plant, although operating within specification, provided increased opportunities for the parasites to pass. This resulted from the operational regime and the problems associated with maintenance operations at the plant. These events also had the potential to mobilise any organisms contained in sediment deposits within the clear water tanks or the bypass channel.

The efficiency of the plant in removing *Cryptosporidium* and *Giardia* during the Second and Third Events is the subject of major disagreement between AWS and Sydney Water. During this period, the plant was run at an optimal operational level and turbidity and particle counts were well within "world's best practice". AWS also point to the prototype results in support of its contention that the levels of contamination recorded by AWT in the distribution system are unreliable. Its own testing showed only low levels in treated water.

Sydney Water and AWT argue that their tests are reliable and supported by overseas laboratories. While accepting the plant's record in terms of turbidity and particle removal during the Second and Third Events, they express a concern that the plant may be allowing the passage of excessive *Cryptosporidium* and *Giardia*.

The First Event (21 July to 4 August)

I conclude that the cause of the contamination in the First Event is most likely to be a combination of the increased levels of *Cryptosporidium* and *Giardia* in the raw water entering the plant in July some of which the plant allowed to pass. Although operating within specification, the operational regime and problems associated with maintenance of the plant provided increased opportunity for the passage of pathogens. These events also had the potential to mobilise any organisms contained in sediment deposits in the bypass channel. However, these occurrences were probably insufficient to have resulted in the extremely high readings found in the distribution system. Those high readings were probably the result of the flushing out of organisms which had accumulated in the distribution system.

The Second Event (24 August 5 September 1998)

Further significant contamination of the system was identified on 25 August. By this time, because of the earlier events, the operation of the Prospect plant had been modified to achieve optimum performance. This was done by adjusting the hydraulic throughput of the plant and ensuring that the coagulation process was functioning effectively. Notwithstanding these measures, organisms passed through the plant and were measured in the supply system immediately downstream, including one reading in the treatment plant laboratory.

I am of the view that the Second Event is likely to have been caused by the inflow of extremely high levels of organisms into Warragamba dam during the major rainfall events. Contaminated water was taken from the thermocline into the treatment plant and passed through into the distribution system. The levels of contamination cannot be authoritatively determined.

Third Event (5 September to 19 September)

The Third Event was a continuation of the Second Event. Although there were no significant new rain events, the *Cryptosporidium* and *Giardia* that had been washed into the watercourses during the previous rainfall is likely to have remained in the dam. The thermocline containing high levels of *Cryptosporidium* and *Giardia* was still present.

The cause of the Third Event was the same as the Second Event. Very high levels of *Cryptosporidium* and *Giardia* in the raw water caused some levels of pathogens to pass through the plant into the distribution system.

Chapter 7: Efficiency of the treatment plants

How is Sydney's drinking water treated?

Since late 1996, all of Sydney's water supply has been filtered. Eleven water treatment plants are used to filter drinking water supplied to Sydney, Illawarra and the Blue Mountains. Seven of these facilities are owned and operated by Sydney Water. These are located at Orchard Hills, Cascade, North Richmond, Nepean, Warragamba, Linden and Greaves Creek.

The remaining four privately-owned and operated plants at Prospect, Macarthur, Illawarra and Woronora provide filtered water under contract to Sydney Water. These four plants provide more than 90% of Sydney's drinking water.

The locations of the major water filtration plants are shown in the appendices.

Conventional water treatment includes a series of steps including coagulation, flocculation, sedimentation, filtration and disinfection. There are several other forms of water filtration, which incorporate some or all of these steps. Water filtration plants in Sydney have generally used alternatives to conventional treatment because the raw water was deemed to contain low levels of pathogens and to be consistently high in quality.

A process of contact or direct filtration is used for all of Sydney's water, with the exception of water supplied through the North Richmond, Orchard Hills and Nepean plants.

North Richmond, which has a run of river water supply, uses dissolved air flotation and a clarification process followed by filtration using granular activated carbon contactors. Nepean, which has high levels of color and turbidity from time to time, uses a process of absorption, clarification and filtration. Orchard Hills includes a sedimentation phase. Disinfection for all plants is achieved after filtration by a chlorination process and fluoride is added to protect dental health.

Coagulation and flocculation

The particles that are removed from drinking water can be as small as one hundred thousandth of a millimeter (0.01 microns). The larger the particles, the more easily they are removed. Smaller particles are removed by making them stick together using a process known as coagulation. The small particles usually have a negative charge. By adding a suitable compound with a large positive charge, the negatively charged particles will clump together. These compounds are called coagulants and are usually ferric (iron) or aluminium salts that dissolve in water to form positive ions which attract the negatively charged particles. This process is sometimes enhanced by adding positively charged (cationic) polymers. After the coagulant is added and mixed in the water, particles clump together to form structures called floc.

Flocculation is the next stage. The size of the floc is increased, making it easier to remove by filtration or settling. The flocculation process is frequently aided by slowly stirring the water using large paddles, making the floc particles gently collide and stick together. If the water is agitated too hard, the larger floc will be ripped apart. To strengthen the large floc, a polymer is frequently added during the flocculation stage.

Clarification/settling and filtration

Sometimes known as conventional filtration, this process removes particulate matter in two steps. Coagulants are added to the water and floc is formed, as described above. Following formation of the floc, the water travels through settling tanks where most of the floc is removed by gravity. The settling tanks may be horizontal flow chambers where the water travels slowly through the chamber for several hours. Alternatively, they may be more compact structures called clarifiers where the water rises slowly through a vertical chamber and the clarified water is decanted from the surface into troughs. Whatever floc remains after settling is screened out using filters containing single, dual or multiple layers of media. Alternatives to conventional clarifiers are absorption clarifiers or roughing filters of either a coarse artificial or granular media. These clarifiers and roughing filters remove large floc prior to polishing filtration. For large municipal plants, rapid gravity filters are most frequently used for this purpose. The filters are regularly backwashed to remove accumulated floc.

Direct or contact filtration

In the process of contact filtration, sometimes known as in-line filtration, a coagulant is added to the water immediately ahead of the filters to form a floc, which is then trapped by the filter. Flocculation tanks are frequently added before the filters to allow more time for the floc to increase in size. This latter process is known as direct filtration. Direct and contact filtration processes differ from conventional filtration by eliminating the settling stage. Although more cost effective than the conventional settling/filtration method, the process requires careful control, particularly in systems where the source water quality varies greatly. Modern instrumentation and control technology provide for reliable operation and management of filtration plants using the direct or contact filtration process.

Dissolved air flotation (DAF)

This method relies on flotation of particles instead of settling as described in the settling/filtration process. Prior to flotation, the water must be treated with coagulants to allow the flocculation process to take place. Air is dissolved in water to create microscopic bubbles. The air/water solution flows up through the flotation chamber carrying floc to the top of the tank where it can be skimmed off. The floc moves upwards as the air bubbles attach to the floc, making it lighter than water. Flotation is frequently used when algae and colour are of more concern than silt or clay particles and is often used for treatment of run of the river water. DAF is effective for the removal of some 90-99% of *Cryptosporidium* and *Giardia* (Plummer et al, 1995).

Granular Activated Carbon (GAC) Contactors

GAC contactors are sometimes used as a supplement to the filtration process. The activated carbon absorbs organic micro-pollutants and taste and odour compounds.

How does the water get to our taps?

A brief description of Sydney's drinking water system is provided in Chapter 3. A diagram of the distribution system is also in the appendices.

Performance of the Prospect plant

Turbidity is the quantity of particles in a water sample. It is a useful measure of water quality and often indicates the presence of contaminants such as faecal coliforms and bacteria. Water suppliers use turbidity monitoring and other measures such as particle counters to help detect the possible breakthrough of pathogens during the treatment process. As required by its contract, Prospect monitors for changes in turbidity to assess whether the treatment process is performing optimally.

The water filtration plant at Prospect operated well within the specifications of the contract with Sydney Water during the entire period of the recent events. The contract specification for turbidity was 0.5 NTU while the target level was 0.3.

The turbidity of treated water at Prospect was usually below 0.3 and did not rise above this figure during the incidents.

During the First Event *Cryptosporidium* and *Giardia* passed through the plant. Maintenance work on the clear water tanks and other plant operations may also have allowed *Cryptosporidium* and *Giardia* to enter the distribution system. Accepting the laboratory results as accurate, it is also likely that some organisms recorded in the First Event had accumulated in sediments and biofilm, and were released by flushing.

No treatment plant can guarantee removal of all *Cryptosporidium* and *Giardia*. The levels of parasites normally present in Warragamba dam are low and appropriate operation of the plant will allow only very small numbers of *Cryptosporidium* and *Giardia* to pass into the distribution system. However, during the Second and Third Events after unusual rainfall, the raw water coming to the Prospect plant

had elevated turbidity levels and contained high levels of *Cryptosporidium* and *Giardia*. The following graph illustrates when levels of *Cryptosporidium* were measured in Prospect's treated water during the three events.

I am satisfied that some of these organisms passed through the plant although the actual levels cannot be accurately determined. Accordingly, it is not possible to reach a conclusion on the efficiency of the plant in removing *Cryptosporidium* and *Giardia* during the Events.

Operation of Sydney's other filtration plants

The operation of the other 10 filtration plants during the incident is described in detail in my Third Interim Report. Cascade, Graves Creek and Linden plants did not record any positive results in either raw or treated water. Nepean, North Richmond and Woronora recorded very low positive levels of 1 or 2 pathogens. *Cryptosporidium* in finished water except for readings on 11 September about which there is considerable doubt on the accuracy of the laboratory results. None of these plants were challenged with highly contaminated water. The highest levels recorded in raw water were Nepean (20 *Cryptosporidium*), North Richmond (8 *Cryptosporidium*) and Woronora (40 *Cryptosporidium*).

Warragamba and Orchards Hills plants shared the highly polluted water from Warragamba dam with Prospect. Both recorded high levels in treated water during the Second and Third Events, in addition to the 11 September result which is again doubtful.

Sydney Water's investigation of the operation of the two plants has revealed a number of significant problems during these periods including:

- inappropriate chemical dosing;
- poor performance at plant start-up;
- automatic shutdown allowing the passage of water through filters;
- automatic flocculation system was unsatisfactory; and
- problems during the automatic backwash cycle when water flowing through the filters is increased and with the end of the backwash cycle when filter media is unsettled.

Sydney Water has now changed the operational procedures at these plants and introduced a number of plant modifications. An action plan to combat the passage of *Cryptosporidium* and *Giardia* in the plants has also been developed.

If the results of 11 September are discounted, the Macarthur plant recorded a high of 24 *Cryptosporidium* and 2 *Giardia* on 28 August when it was treating high turbidity water from Cataract. The plant operated well within specification throughout the events and it is likely that the reading may have resulted from highly contaminated water reaching the plant, or may be due to an over estimate in the number of organisms present in the sample.

Discounting the 11 September results at the Illawarra plant there is only one significant positive result 52 *Cryptosporidium* and
2 *Giardia* on 30 July. The highest level recorded in raw water at the plant was 10 *Cryptosporidium*, indicating a relatively unpolluted catchment. Given that the plant's operation on 30 July was well within specification, the laboratory results on that day may again be due to an overestimation of the number of organisms in the sample.

Plants other than Prospect have not been subject to detailed investigation by the Inquiry.

However, it appears that the plants other than Warragamba and Orchard Hills operated well throughout the period although most were not challenged with highly contaminated water. Sydney Water has identified the problems in the operations at Warragamba and Orchard Hills and is taking remedial action. In addition, the proposed measures to improve catchment and dam management should result in these plants receiving less contaminated water.

All filtration plants are included in the proposed monitoring regimes and their operations should also be subject to ongoing review. Any future operational standards should also apply to them.

Prototype plant

In an effort to obtain more information on the potential efficiency of the Prospect plant at removing *Cryptosporidium* and *Giardia*, I asked that the prototype plant, which was built during the design stage of Prospect, be reactivated for seeding trials with *Cryptosporidium*. Trials with *Cryptosporidium* or *Giardia* were never undertaken in the prototype plant (see Fourth Report). Studies carried out by AWS and Clancy Environmental Consultants since the incidents on behalf of the Joint Action Group provide information about how effective filtration may be at Prospect.

The prototype plant is a small version of the full-scale Prospect Water Filtration Plant. The plant has one filter with an area of one square metre, compared to the full-scale plant which has 24 filters each with an area of 240 square metres. A small-scale plant such as the prototype plant is used by the water industry to test various qualities of raw water entering the plant and various treatment conditions in the plant to estimate how these conditions may affect treatment in the full-scale plant.

The primary objective of the prototype plant testing program was to create controlled conditions in which to develop a better understanding of the potential performance of the Prospect plant in removing *Cryptosporidium* and *Giardia* and other particulate material (algae, clay particles and the like) under a variety of treatment conditions. The material inside the prototype filter (a sand medium) and the water treatment chemicals (iron salts, polymers and lime) added in the prototype plant are the same as those used in the Prospect plant. While it is not possible to replicate exactly all of the raw water quality and treatment conditions of the Prospect plant, the filter at the prototype plant can be challenged with a high concentration of organisms and treatment conditions can be varied.

An experiment in which a large number of organisms is added to the prototype plant to quantify their removal through the filter is called a "seeding" experiment. Two kinds of seeding experiments were performed in the prototype plant: one with the natural, relatively low turbidity raw water from Warragamba pipeline and one with higher turbidity raw water. Each of these experiments was performed twice to verify the removal of organisms. The seeding experiment with low turbidity raw water determined the removal capabilities of the prototype plant under typical raw water conditions. The seeding experiment with higher turbidity raw water was intended to provide a comparison of the plant's ability to remove organisms when the quality of water entering the plant has been affected by unusual conditions such as major rainfall in the catchment.

Experiments were initially performed without seeding to ensure that the prototype plant was performing appropriately. These unseeded experiments also provided information for the subsequent seeding experiments, so the correct conditions for the seeding experiments could be calculated.

After completion of the unseeded experiments, the seeding experiments were performed with natural raw water turbidity levels.

Since Warragamba water had low turbidity at the time of these experiments, the high turbidity seeding experiments were performed using different water from that treated in the Prospect plant. Water from the reservoir at a location deeper than the water entering the Warragamba pipelines had a much higher turbidity. At this very deep location, the turbidity is 10 to 20 times higher than the water at shallower depths. This water was pumped from the bottom of the reservoir into tanker trucks for delivery to the prototype plant. The water from the tanker trucks was mixed with the low turbidity Warragamba pipeline water as it entered the prototype plant to produce a turbidity of approximately 10 NTU.

Operation of the prototype plant

The Joint Action Group provided me with the following conclusions about the operation of the prototype plant:

- "baseline filter runs using natural low-turbidity and the blended high-turbidity raw water achieved treated water qualities and filter runs consistent with the performance of the full-scale Prospect WFP during August and September 1998;
- in the low-turbidity seeding run conducted by Clancy Environmental Consultants (CEC), *Cryptosporidium* removal ranged from 4.7 (99.998%) to more than 6.4 (99.99996%) log in all samples, and averaged >5.0 log (99.999%) during the filter run;
- a minor filter effluent turbidity peak from the steady-state level of 0.01 to 0.02 NTU to 0.12 NTU occurred during the low-turbidity seeding run conducted by CEC, associated with an unplanned shut down of the ferric chloride feed system. Filter effluent sampling during the one hour peak indicated that *Cryptosporidium* removal during the turbidity peak was still highly effective (4.7 log/99.998%);
- in the high-turbidity seeding run conducted by CEC, *Cryptosporidium* removal ranged from 5.2 (99.9994%) to more than 6.3 log (99.99994%) in all samples and averaged >5.0 log (99.999%) during the filter run;
- *Cryptosporidium* removal in natural, low-turbidity seeded raw water exceeded 3.0 log (99.9%), averaged over the filter run, in the initial, screening-level seeding run (Thames Water sampling and analysis);
- *Cryptosporidium* removal in the blended, high-turbidity seeded raw water exceeded 3.5 log (99.968%), averaged over the filter run, in the initial, screening level seeding run (Thames Water sampling and analysis);
- *Cryptosporidium* removal during ripening was consistent with the removal during steady-state operation in all seeding runs. Although turbidity and particle counts were higher during filter ripening than steady-state operation, the *Cryptosporidium*, spore and algae data collected in the prototype tests indicated that these microbial parameters were effectively removed during ripening, even when the filter effluent turbidity exceeded 0.1 NTU. Based on the prototype testing data, there is no evidence that filter-to-waste would improve the overall removal of *Cryptosporidium* through the plant. Filter to waste means that at the beginning of a filtration run ie. immediately after backwashing, known as the ripening period, water does not go into supply but is returned to head of works.
- algal removal exceeded 3.0 log (99.9%) in samples collected during steady-state operation. Algal removal during ripening was as effective as during steady-state operation;
- in general, aerobic spore concentrations in the raw water were too low to provide a useful indication of *Cryptosporidium* removal; and
- quality control results from the prototype testing demonstrated acceptable data quality in terms of completeness, representativeness, precision and accuracy."

Particle and spore results from the prototype testing demonstrated that the level of removal can be highly dependent on the raw water concentration. Furthermore, when raw water particle concentrations are low, very small differences in filter effluent concentrations that are not significant from an operational or filter performance perspective, will determine whether or not the removal goal is achieved. Thus, a particle removal goal may not be appropriate under all raw water quality conditions.

Filter effluent particle counts were shown to be influenced at times by biological activity in the filter beds. Absolute limits on filter effluent particle counts have been determined to be site specific. A substantial seasonal database should be developed before establishing target filter effluent particle counts for a specific plant.

Conclusions on the prototype plant

The operation of a prototype plant gives a measure of the performance capability of the process being investigated. It does not, of course, give a measure of how the plant operates all of the time. Nonetheless, the data from the prototype plant demonstrates that the type of filtration in use at Prospect is capable of removing substantial amounts of *Cryptosporidium*. The average removal of *Cryptosporidium* during these experiments always exceeded 99.9% (3 log) and in some cases was as high as 99.999% (5 log). In one trial, however, the removal did drop below 99.9% (3 log) towards the end of the filter run. It is not possible to determine if this was a trend or one aberrant result. Further testing is required.

It is relevant, however, since this may show that towards the end of a filter run, the removal of *Cryptosporidium* may be less efficient. This would be particularly relevant as the filter run times that were used at Prospect during the First Event were considerably longer than those used during the prototype plant trials.

AWT has made a submission that suggests the current industry practice of using "killed" oocysts for performing treatment removal studies may give misleading results. It has supplied evidence that shows that the surface charge of killed oocysts is different from that of live oocysts. It concludes that the killed oocysts used in the prototype plant trials may have been more readily removed than live oocysts that occur naturally. Insufficient studies have been performed to enable firm conclusions to be drawn.

AWT has also raised with me the possibility that variations in pH level may affect the ability of filtration to remove *Cryptosporidium*. This may serve to confound the results, and the tests with the prototype plant have not included variation in pH levels.

I am conscious of the limitations of using a prototype plant. It is impossible to effectively mirror the operation of the Prospect plant. However, the studies do demonstrate that the process used at Prospect plant is capable of removal of 99.9% (3 log) of *Cryptosporidium* over the duration of a filter run. It is possible, however, that extended filter runs may allow the passage of higher numbers of oocysts and that other factors such as pH levels may allow passage of high numbers at particular times.

I recommend that the prototype plant be maintained for use in the further testing and research outlined in the Research chapter of this report.

Chapter 8: *Cryptosporidium* and *Giardia* a picture of uncertainty

Introduction

Since the publication of my Third Report, I have received many detailed submissions regarding the data generated by the AWT laboratory during the contamination events. I have also had detailed discussions with AWT which has supplied additional material. Consideration of this has led to some modification of my interim conclusions on the quality of data supplied and the causes of the events.

AWT were invited to meet with the Inquiry and comment on the draft Third Report prior to its publication. It decided not to make any comment or submission. There are some misconceptions about the Third Report that should be discussed.

AWT apparently feels that the Third Report suggests that the entire laboratory has inadequate quality control. This was not my intention. My investigations have been confined to that part of the laboratory which performs parasite analysis. AWT also believes that the Report suggests that I intended it should cease to perform parasite analysis. This is not the case. My concern is that a laboratory independent of Sydney Water and other water authorities should be available for testing for public health and other regulatory purposes. AWT should continue to have a role for Sydney Water and other clients. The management of AWT must determine that role. I am not in a position to make a definitive judgment about AWT's technology. However, it must be understood that it is not widely used and has not been extensively validated.

Why is it so hard to find out what was in Sydney's water?

The potential for transmission of *Cryptosporidium* from water to humans has only been recognised in recent years, starting with the first documented waterborne outbreak in Texas in 1984 (Rose, 1997). The methods for detecting its presence in water are new and evolving (Fricker et al 1997). The detection of both *Cryptosporidium* and *Giardia* relies upon microscopic examination of material which has been captured and concentrated by some form of filtration. Although many methods have been described in the scientific literature, there is little agreement on the quality of the methods, their efficiency or reliability. Most methods in use have not been fully validated. The scientific community is in constant debate about the quality and health consequences of the results.

Of particular concern is the ability of analysts to identify *Cryptosporidium* and *Giardia* accurately. Many of the current tests rely upon a subjective assessment and mistakes are made. In a recent event in the UK, a water company issued a boil water alert after claiming to have found *Cryptosporidium* in the water. Subsequent expert examination showed that the particle detected was an algal cell and not a *Cryptosporidium* oocyst. Many algae are of similar size and shape to both *Cryptosporidium* and *Giardia* and may be easily confused without the help of recently developed specialised tests.

Of the six species of *Cryptosporidium* currently defined, only C. parvum has been reported to infect humans. Other species that could be detected as *Cryptosporidium* oocysts in waters include: C. baileyi and C. meleagridis (birds); C. muris (rodents); C. serpentis (reptiles); and C. nasorum (fish). No reliable test exists for the routine identification of specific species of *Cryptosporidium*.

Detecting parasites

There is no method of testing which allows constant monitoring for parasites. Given the likely patchy or clumpy occurrence of parasites in water (Teunis et al, 1997), reliance on single grab samples to assess water quality may be unreliable. So care is needed to ensure that samples of sufficient volume are taken at the correct frequency. It is possible to adjust the size and frequency of sampling if the range of likely contamination is known, if assumptions are made about the distribution of parasites within a water body, and if the efficiency of the methodology is accounted for (Nahrstedt and Gimbel, 1996).

The methods available for the detection of *Cryptosporidium* oocysts and *Giardia* cysts in water involve three stages:

1. sample collection and concentration;
2. separation of oocysts from contaminating debris; and
3. detection of the oocyst (or its contents) and determination of viability.

No single method is suitable for testing all water samples. Different laboratories across the world use different techniques, often resulting in a wide variation in results. There is sometimes complete disagreement between laboratories on whether or not parasites are present and there is often disagreement on the measured concentrations.

In one study in North America, considerable variation was noted between laboratories using the same methodology, with many laboratories recording false positive and negative results (Clancy et al, 1994). The efficiency with which laboratories recovered *Cryptosporidium* and *Giardia* from water was shown to be about 10%, meaning that 90% of the organisms were not found. This was determined from controlled trials with water intentionally seeded with *Cryptosporidium* and *Giardia*.

Stage 1: Sample collection and concentration
How are samples collected?

The early methods used for the detection of *Cryptosporidium* oocysts used a procedure originally developed for the detection of *Giardia* intestinalis cysts (Badenoch, 1990). In this method, large volumes of water (100-1,000 litres) were concentrated using yarn-wound filters. After concentrating the sample, the filter was cut open and the concentrated material resuspended with the aid of a weak detergent solution.

This method was valuable in establishing that oocysts were present in water samples but it produced mixed results with recovery efficiencies being as low as 1%. The yarn-wound filter method has largely been superseded by other methods which are more efficient. Two new methods of concentrating samples became generally available in the early 1990s. One utilises membrane filtration (Ongerth and Stibbs, 1987) and the other a calcium carbonate flocculation procedure (Vesey et al 1993a).

In the membrane filtration method, water is passed through a large flat membrane with the retained material being washed off the surface and collected for further processing. Problems may arise when

the membrane becomes blocked, resulting in water or solids being lost when the membrane housing is opened. A problem of cross-contamination may also result from the use of a pre-filter (used to reduce membrane blockages) if it is not adequately cleaned between samples.

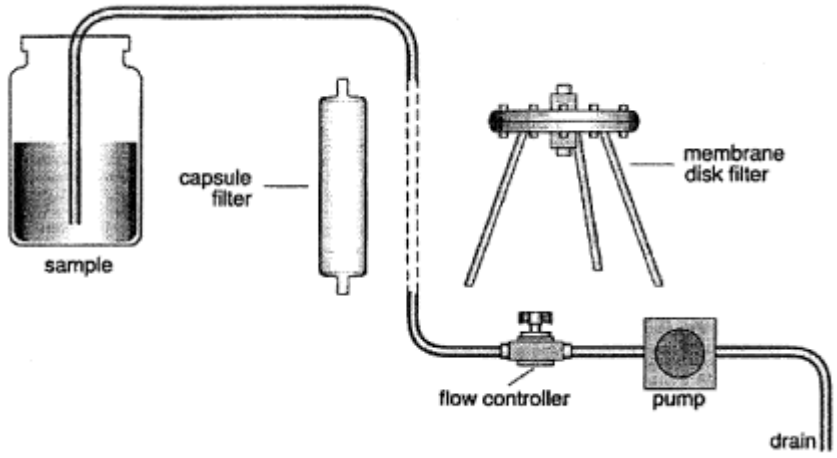
In the calcium carbonate flocculation method, a floc of finely dispersed calcium carbonate is produced in the water sample by the addition of calcium chloride and sodium bicarbonate, followed by raising the water's pH. The calcium carbonate is then allowed to settle, together with the *Cryptosporidium* and *Giardia* and other particulate matter.

Both of these procedures give higher recovery percentages and are more reliable than the yarn-wound filter method. However, they have their drawbacks. The membrane filter method is only practical for large volumes of water if the sample is relatively clear. The flocculation method can generally only be used on volumes of water less than 20 litres, irrespective of the water quality. The extremes in pH resulting from the flocculation method can also have the effect of killing some oocysts, which is a disadvantage if it is important to determine viability.

Further methods of sample concentration have recently become commercially available. Some of these have been incorporated into the US Environment Protection Agency (US EPA) draft method 1622 for detection of *Cryptosporidium* and *Giardia* (US EPA, 1997). Method 1622 allows for various approved steps to be used to process samples. The simplest concentration option is a capsule filter, such as Envirochek™, but it has been noted that the current Envirochek™ filter is only suitable for the concentration of up to 20 litres of water (Matheson et al 1998). Several other scientists have reported recovery efficiencies which range from 70-80%. Although these recoveries may not be achievable for all types of water, they are considerably higher than those obtained by the yarn-wound filters.

The flat bed membrane disk filter mentioned above, has been shown to give recoveries as high as 90% for large volume samples (100-1,000 litres), but in its present format is only suitable for relatively clean waters. See Figure 1 for an overview of both concentration methods.

Figure 1: Laboratory filtration system for capsule filter or membrane disk filter (page 43, Method 1622, US-EPA 1997)



Stage 2: Separation of oocysts and cysts from background debris

A large amount of extraneous material, which is present in water concentrated with *Cryptosporidium* and *Giardia*, needs to be removed to allow a meaningful assessment of *Cryptosporidium* and *Giardia* numbers. Various techniques are used to achieve this separation.

The major techniques for separating oocysts and cysts from other particles are:

Flotation

This involves flotation of material on a sucrose or Percol-sucrose solution. This technique tends to lose oocysts and cysts, and to concentrate other material, which is not required and may interfere with the microscopic examination of parasites. Notwithstanding these limitations, it is a widely used separation process (US EPA, 1996).

Immunomagnetic separation (IMS)

IMS is one of the newer technologies approved in Method 1622 for the separation stage. It involves the attachment of specific antibodies to magnetisable particles, mixing the particles with the samples and then separation of the parasite-bound magnetisable particles from the remaining debris. The technique is simple, but there are many potential causes of failure. Recovery rates of over 90% have been reported in relatively clean waters. In highly turbid samples, recovery may be significantly reduced.

Flow cytometry

This was initially used in the United Kingdom in an attempt to detect *Cryptosporidium* oocysts in environmental samples. It was found, however, that the sensitivity of the instruments used was not sufficient to distinguish oocysts. The technique was modified to improve separation in order to identify different cells (Vesey et al, 1993b; Vesey et al, 1994). Water concentrates are stained in suspension with an antibody that is tagged with a fluorescent label and passed through the fluorescent activated cell sorter. *Cryptosporidium* and *Giardia* are sorted on the basis of size, shape, and fluorescence characteristics. The sorted material can be collected on a microscope slide and viewed by epifluorescence to identify the presence of cysts and oocysts (Figure 2).

Figure 2: Membrane concentration-flow cytometric separation steps prior to microscopic enumeration of parasites

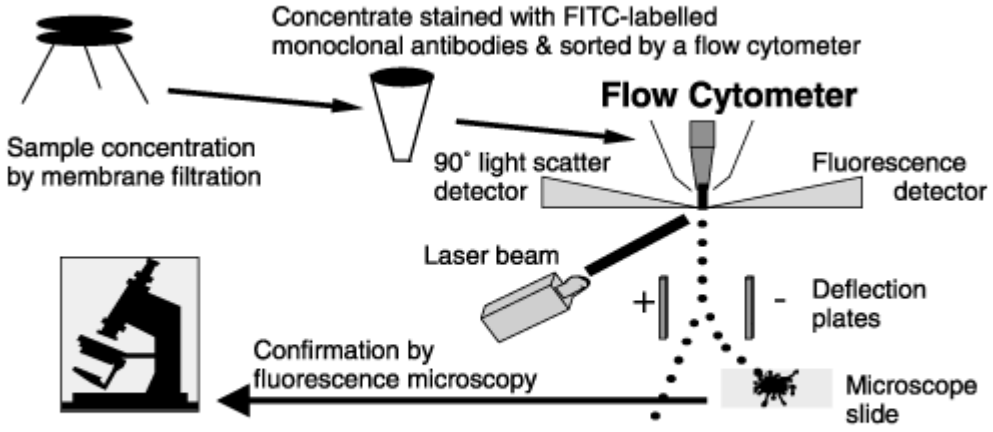


Figure 2: Membrane concentration-flow cytometric separation steps prior to microscopic enumeration of parasites

Stage 3: Methods for detecting and counting cysts and oocysts

My Second Report commented on the current scientific debate whether *Cryptosporidium* and *Giardia* were accurately identified in Sydney's water. It was suggested, for example, that the organisms might be algae. This debate was resolved when all of the experts agreed that samples showed *Cryptosporidium* and *Giardia* present in Sydney's drinking water at levels that were of public health

concern. Further work, now completed, has confirmed that *Cryptosporidium* and *Giardia* have been identified. However, the numbers counted may not always be accurate.

The process for counting the number of parasites recovered in a water sample is done using a microscope.

Epifluorescence microscopy

Routine detection of parasites relies on the use of an epifluorescence microscope, which allows the identification of *Cryptosporidium* oocysts and *Giardia* cysts using set identifiers including size, shape and bright green fluorescence which are shown up through an antibody stain. This antibody staining is referred to as an immuno fluorescent antibody (IFA). Samples may be stained in suspension, on a microscope slide or on a membrane prior to microscopic examination. This procedure will identify all six species of *Cryptosporidium*, but cannot specifically identify C. parvum the only species known to be a problem for human health (Fayer, 1997).

There are difficulties in distinguishing some algae, which mimic the appearance of *Cryptosporidium* or *Giardia* (Rodgers et al, 1995; US EPA, 1997). Hence, confirmation of oocysts and cysts necessitates additional steps, such as staining with the fluorescent dye, DAPI (4',6'-diamidino-2-phenylindole) (EPA Method 1622) and in the future, potentially by the use of molecular methods currently under development (Rochelle et al, 1997a; Vesey et al, 1997; Kaucner & Stinear, 1998).

The issue of viability

Only a subset of live C. parvum is known to cause infections in humans. The numbers of oocysts required to cause infection may be as low as 1-10 to over 1,000, depending on the strain of C. parvum (Chappell, 1998). Considerable research has been undertaken to develop reliable viability tests for oocysts (Campbell et al, 1992; Robertson et al, 1993; Belosevic et al, 1997; Rochelle et al ,1997b; Slifko et al, 1997). These procedures may not always identify oocysts that are infectious.

Accordingly, the significance of finding oocysts in treated waters is not always clear. Some of the organisms that are detected may be nonviable and pose no threat to public health. Because of these uncertainties, if oocysts are found in drinking water, it presently must be assumed that they could be C. parvum and viable for the purpose of making a public health decision (Badenoch et al, 1995). For reasons discussed in chapter 9, it now seems likely that the *Cryptosporidium* found in Sydney's water was not infectious to humans during the recent events. I am satisfied, however, that a conservative public health response was appropriate.

Issues for public health

The most important issue in analysing the presence of waterborne parasites is the reliability of the method used. Standardised methods that allow meaningful comparisons between results have recently been published although not yet fully validated by the US EPA (Method 1622). Similarly, in the United Kingdom, a standard method is being developed for regulatory testing of drinking water. In Australia, there is currently no accreditation service available for the testing of water samples for parasites and a variety of unvalidated methods are used. The Inquiry met with representatives of NATA (National Association of Testing Authorities), the national accreditation service, which advised its intention to introduce an accreditation system for parasite testing in 1999. The lack of standardisation of methods and comparability of different laboratory results makes interpretation of data difficult. This has led to disagreement on the level of parasites present in Sydney's drinking water between Australian Water Services (AWS), the operator of the Prospect plant, and Australian Water Technologies (AWT), during the recent events.

In environmental samples, empty oocysts or shells are frequently detected, which are of no health significance. When analysing waters, only whole oocysts containing stainable cellular components

(such as those with the stain DAPI) can be confirmed as being oocysts. Those which are empty or do not stain with DAPI may not be oocysts and these should be referred to as *Cryptosporidium*-like bodies. During the recent events in Sydney, the AWT laboratories did not use the DAPI confirmatory stain and many empty shells with no internal contents may have been counted as *Cryptosporidium*. This may have contributed to the extraordinarily high levels of oocysts recorded. Sydney Water was aware of this. I am advised that since mid September, DAPI staining has been used at AWT for examination of routine samples.

Laboratories involved during the events

Sydney Water's laboratory AWT

Australian Water Technologies (AWT) was established in 1993 as a wholly owned subsidiary of Sydney Water. One division within AWT, Environment, Science and Technology, undertakes water quality testing for Sydney Water and other clients. It competes commercially with other laboratories and consulting companies.

The majority of microbiology work undertaken in the laboratory is routine bacteriological water testing. There is a smaller research-based group that undertakes *Cryptosporidium*, *Giardia* and virus testing. AWT operates regional laboratories in Melbourne, Brisbane and Forster.

The Sydney-based laboratory meets the requirements for Laboratory Registration and Quality System Certification (ISO9001) and is NATA (National Association of Testing Authorities) accredited for most of its operations. Although requested by AWT in 1997, specific NATA accreditation for parasites (including *Cryptosporidium* and *Giardia*) is not yet available. In the absence of NATA approval, AWT has been involved in an international program for parasite testing known as Laboratory Environmental Analysis Proficiency (LEAP), which is based on samples sent from Yorkshire Water, UK. Thirteen other international laboratories are involved in the LEAP program.

The AWT laboratory uses the flat bed membrane system for concentrating water samples. This should give high recovery efficiencies. Following filtration, the AWT laboratory uses flow cytometry to separate *Cryptosporidium* and *Giardia* from other material. Some samples that are high in suspended matter are sent, however, to their research collaborator's laboratory at Macquarie University for IMS and flow cytometry. These techniques should enable high recoveries of parasites. However, neither of these methods has been fully validated in the AWT laboratory. The relatively high recovery efficiency, which should be attainable using the above methods, may explain in part why the levels of *Cryptosporidium* and *Giardia* recorded in Sydney's drinking water were higher than levels previously recorded overseas.

Other laboratories utilised during the events

AWT's Melbourne laboratories

AWT's laboratory in Melbourne (Water ECOscience, Mt Waverley, Victoria) has developed a molecular presence/absence test for *Cryptosporidium* and *Giardia* based on a modified polymerase chain reaction (RT-PCR). This attempts to specifically identify viable parasites (Kaucner and Stinear, 1998; Water ECOscience methods WEM6.4i for oocysts, WEM6.5i for cysts). This laboratory was used to examine 19 samples during the First and Second Events.

Macquarie University

Macquarie University has been instrumental in developing the flow cytometry methods used at AWT. It has stated that the antibodies now used at AWT for the fluorescent staining (IFA) of oocysts and cysts are superior to those used by others. AWT in a submission to me states that the use of these antibodies provides better sensitivity to their method. No evidence which confirms this claim has been made available by AWT, although the performance of the antibody has been reported in the scientific literature by Macquarie University.

Macquarie University had not been involved in routine parasite testing until it was called to assist with AWT's work overload during the recent events. In particular, Macquarie University undertook IMS and flow cytometry on samples concentrated at AWT during the events. It also assisted with DAPI staining of some slides and testing of a novel molecular stain.

The molecular stain under development by Macquarie University uses nucleic acid probes that target the 18 S rRNA molecule (a molecule present in high concentration in all living cells). Molecular probes apparently specific to C.parvum have been designed to bind to the sporozoites within the oocysts, using a method called fluorescent in situ hybridisation (FISH) (Vesey et al 1997; 1998). The FISH procedure requires further chemical and physical treatment of slides produced during flow cytometry, which may lead to some losses of oocysts from the sample. Only a subset of oocysts that contain many rRNA molecules will be stained by the FISH method. Conditions that result in the loss of rRNA molecules within oocysts are not yet understood.

It has been claimed that the FISH technique can distinguish C. parvum from other cryptosporidia and that it will only detect live oocysts (Vesey et al, 1997). However, these claims have not been fully validated for use with routine water samples.

The AWT laboratory uses *Cryptosporidium* oocysts and *Giardia* cysts for its control material for checking that their procedure recovers the organisms. It has been suggested that this control material may have been the source of some contamination within the laboratory. This was denied by AWT. One of the arguments put forward was that the oocysts had been killed by gamma irradiation and accordingly would not give a positive reaction in the FISH test. This argument is not supported by studies which I commissioned and showed that the gamma irradiated (killed) oocysts used for positive control spikes give a very strong FISH positive result. I understand that this does not necessarily mean that the FISH test is a poor indicator of viability of oocysts, which have died in other ways, although further studies are required.

FISH is not used at the AWT laboratories. The expert panel requested its use on a small number of samples by Macquarie University in an attempt to determine whether the *Cryptosporidium* oocysts that were seen during the events were C. parvum. Although only low numbers of oocysts were observed by the FISH staining in many cases, the results do indicate that in some samples, C. parvum was likely to be present.

Thames Water Utilities, UK

Sydney Water and AWT have previously consulted Thames Water's laboratory in Reading, England when possible parasites in Sydney's drinking water were identified in 1997 and 1998, all prior to the recent events. Thames provided back up DAPI staining and advice during those minor events. During the Second Event, a few hundred slides (from the First Event) were also taken to Thames for confirmation DAPI staining and possible molecular identification of *Cryptosporidium*. Thames reported the results of these slides as "presumptive" and "confirmed". Presumptive results mean that the particles observed are of the same size and shape as *Cryptosporidium* or *Giardia* and that they fluoresce. Confirmed results mean that internal structures were consistent with *Cryptosporidium*. Many of the presumptive oocysts were empty shells and therefore could not be definitively identified as oocysts. This does not mean that they were not oocysts. They may have been oocysts that had died or they may have been some other type of cell. It is impossible to be definitive. I will discuss this issue later in this report.

Thames also provided parasite analysis on raw and filtered waters collected and stored (4-8^{o} C) from the apparent event period 9-12 September 1998. Waters (20 litre samples) were concentrated by Envirochek^{TM} cartridges, separated by IMS and examined by IFA microscopy. Only very low levels of *Cryptosporidium* or *Giardia* were found in a small number of samples. Samples analysed from this period by AWT showed high numbers of *Cryptosporidium* and *Giardia*.

Australian Water Services/CIRSEE Laboratories

Australian Water Services (AWS) established a parasitology laboratory at the Prospect plant following the Second Event in August 1998. A scientist from the Suez-Lyonnaise des Eaux laboratory in Paris

(CIRSEE) was brought in to run the laboratory using CIRSEE's methods, and additional material was sent to its Paris laboratory for analysis.

The methods employed were based on the Envirochek^{TM} concentration of 20-1,000 litres of water, Percol-sucrose gradient separation of parasites and fluorescence microscopy of IFA stained material. No DAPI confirmation staining is reported by the AWS laboratory. Performance data for the method undertaken in Sydney are not available, however duplicate samples which were sent overseas used confirmatory techniques.

AWS undertook extensive analysis of raw and treated waters at the Prospect plant during the period of the Third Event. In addition, AWS commissioned the University of New South Wales during the Second Event, and Clancy Environmental Consultants (USA) during the Third Event, to evaluate samples.

The University of New South Wales laboratory used flat bed filtration, sucrose-gradient separation prior to IFA staining and microscopy. No performance data have been provided for the University's analyses, and they were involved in a limited number of samples.

US laboratories

Two US laboratories, approved by the US EPA for their current Information Collection Rule (ICR) analysis of parasites from waters, were chosen for re-evaluation of selected samples (Clancy Environmental Consultants, St Albans, Vermont; CH Diagnostics, Loveland, Colorado).

The methods used by the two US laboratories have been validated, with ongoing quality checks being undertaken by the US EPA. Both laboratories used the 1622 method approved steps (Envirochek^{TM} sample concentration for unprocessed waters, IMS separation for oocysts and Percol-sucrose separation for cysts, then IFA staining and microscopy).

University of Arizona infectivity assessment

Parasites concentrated by flat bed filtration at AWT and separated by IMS at Macquarie University were sent to the Department of Veterinary Science and Microbiology, University of Arizona, for mouse infectivity assessment. This laboratory is regarded as one of the best available for this work.

Briefly, the procedure for the infectivity study comprised obtaining pregnant mice (CD-1 dams from Charles River Laboratories) and oral inoculation of their neonatal offspring (five to six days old) with various doses of concentrates or control samples. Infection was determined by examining formalin fixed, stained sections of the terminal ileum removed from each animal at necropsy seven days after inoculation. Eight mice received water concentrates and 48 received positive or negative control material that had also been sent with the Sydney parasite samples. No infections were demonstrated in the mice that were given environmental oocysts. While not totally conclusive, this result strongly suggests that the *Cryptosporidium* present in Sydney's water supply was not infectious for humans. The mice used in these studies are not, however, susceptible to all strains of *Cryptosporidium*. Therefore, the *Cryptosporidium* may have been infectious for humans but not for the mice used in this experiment.

CSIRO Marine Research, Hobart differentiating faecal sources

The ability to use chemical biomarkers (faecal sterols) to distinguish human from herbivore-derived faecal matter was first demonstrated by CSIRO (Leeming et al 1994). The principal human faecal sterol is coprostanol (5β(H)-cholestan-3β-ol), which constitutes approximately 60% of the total sterols found in human faeces. The C29 homologue of coprostanol excreted by herbivores is 24-ethylcoprostanol (24-ethyl-5β(H)-cholestan-3β-ol). It is therefore possible to determine the contribution of faecal matter from these two sources relative to each other by calculating the ratio of coprostanol to 24-ethylcoprostanol in human and herbivore (kangaroo, sheep, cow, etc.) faeces (Leeming et al 1996). Other animals ubiquitous in urban areas such as dogs and birds either do not have coprostanol in their faeces or it is present in trace amounts identifiable as non-human and/or non-herbivore based on the ratios of 5β/5α stanols (Leeming et al 1998). Refinements utilising ratios of

other faecal sterols and faecal indicator bacteria to faecal sterols have further improved the differentiation of faecal sources for a number of water types (Leeming et al 1996, 1998). Forty-two samples of water from Warragamba and Cataract dams were sent for the evaluation of faecal sterols at CSIRO. The presence of a human-specific virus to the bacterium Bacteroides fragilis strain HSP40 (Grabow et al 1995) was undertaken at the University of New South Wales.

Is the laboratory work reliable?

First Event: 21 July 4 August

In the Second Interim Report I discussed the likelihood of the inflow of contamination from:

- sources within the catchment which may have passed through the Prospect plant and entered the distribution system;
- changes in the operation of the plant itself, which may have allowed the introduction of *Cryptosporidium* and *Giardia* into the distribution network; and/or
- inflow of contaminated material immediately downstream of the treatment plant.

I am now satisfied that it is unlikely that the introduction of organisms into the network immediately downstream of the Prospect plant significantly contributed to the contamination.

AWT's results during the First Event initially showed low numbers of *Giardia* and/or *Cryptosporidium*, with higher numbers during mains flushing, as indicated by sampling of city hydrants. The persistence of oocysts and cysts in sediments, along with their occurrence in dirty water flushed from mains is consistent with low numbers of parasites accumulating over time in the drinking water distribution system. As I discussed in my First Report, I have received submissions from AWS who claim the results generated by AWT were not reliable. Similarly, other such claims were made in the media but, as stated in my Second Report, a group of international experts agreed that there was "unequivocal presence of *Cryptosporidium* and *Giardia* in Sydney's treated water at concentrations that are of public health concern".

Oocysts and cysts were first confirmed by Macquarie University and then by Thames Water with DAPI staining of a few slides. Subsequently, a few hundred slides produced from AWT's flow cytometer were sent for examination by Thames Water in mid-August. The Thames readings confirmed the levels of "presumptive" cysts and oocysts that were reported by AWT but demonstrated that the numbers of organisms that could be confirmed as having internal structures was much lower in some samples. This does not necessarily mean that the AWT results were wrong. The procedure that AWT was using at that time was unable to determine if the organisms it was reporting had internal structures. Thus, while these organisms may have been *Cryptosporidium* and *Giardia*, a tentative identification was made and only a small subset of the total numbers reported. Some of these slides were also stained by the FISH method at Macquarie University, and a number of presumptive oocysts were negative by the FISH test (Table 1) which is consistent with the Thames data. During the event 19 samples were also tested in Melbourne by the PCR test, but all proved negative for viable oocysts and cysts. Only one of the PCR samples was enumerated for parasites (98053984) and it was reported to contain 4 *Cryptosporidium* and 13 *Giardia*.

I have received reports from the Joint Action Group (JAG), Sydney Water and AWT which claim that a build up of organisms in the distribution system is unlikely. JAG concludes that insufficient data are available to accurately quantify the contamination risks. The Sydney Water submission states that *Giardia* would become unrecognisable within one to two weeks in a water distribution system. However, the claim is not supported by the evidence and other advice I have received suggests the claim is unlikely to be correct.

AWT have carried out some theoretical work that suggests that cysts and oocysts would not accumulate to high levels in the distribution system. These arguments may be more significant but the work is preliminary and further confirmatory work is required. At present I believe that it is likely that organisms which had accumulated in the distribution system contributed to the high levels reported in some samples. The coincidence of the initial period of flushing and the high levels is so strong that

substantial evidence would be required before a correlation could be denied. In particular, there were high levels associated with turbid water sampled from hydrants. The significance of the contribution is not known for most samples, although in the hydrant samples many of the *Cryptosporidium* and *Giardia* may have been accumulating over time. Further work is required to confirm whether *Cryptosporidium* and *Giardia* accumulate in sediments or biofilms.

In early September, seven water samples collected but stored at room temperature at AWT were reanalysed and the results compared against two independent US laboratories. Two of the samples reanalysed were from the First Event. One drinking water sample (Llewellyn Street, Rhodes, 29/7/98) originally reported to have 35 oocysts and seven cysts, returned none on re-examination. The second drinking water sample (Bate Bay, Cronulla, 29/7/98) originally reported to contain 286 oocysts and eight cysts, returned 1-5 oocysts and 3-8 cysts, with good agreement between all laboratories on the reanalysed samples. Degradation of parasites in samples stored at room temperature could be expected, with *Cryptosporidium* oocysts believed to persist far longer than *Giardia* cysts. Given the lack of degradation in the *Giardia* measured it is likely that *Cryptosporidium* oocysts were originally overestimated by AWT in these samples.

AWT submits that as these samples may not have been stored correctly, they should not be used as a measure of the accuracy of the initial readings. It also submits that it recovered more *Cryptosporidium* and *Giardia* than the other laboratories for some samples. There may be substance in their submission. I have received quite recent advice regarding studies of the survival of *Cryptosporidium* oocysts in water. Dr Giovanni Widmer, a parasitologist at Tufts University in the USA has reported his preliminary findings which have shown that some strains of *Cryptosporidium* die and become undetectable in much shorter time periods than previously assumed. This could explain the disappearance of the *Cryptosporidium* from the stored samples. However, his work is preliminary and further work is required.

Table 1 Confirmation data available on high values reported by AWT during the First Event

Sample ID	Sample Date	Location	AWT Results per slide read		FISH test Crypto.	Thames Result for DAPI* per slide read	
			Crypto	Giardia	+ / total No.	Crypto	Giardia
98053989A	24/07/98	Art Gallery hydrant	10	106	0/5	0	28
98053989B	24/07/98	Art Gallery hydrant			0/4	0	20
98053989C	24/07/98	Art Gallery hydrant			Not tested	1	11
98053990	24/07/98	Museum College St hydrant	140	461	1/59 (2%)	130	20
98054003	25/07/98	Museum College St hydrant	170	332	Not tested	30	253
98054004	25/07/98	Art Gallery hydrant	200	963	Not tested	7	92
98054476	28/07/98	Main city tunnel	24	27	Not tested	6	10
98054675	29/07/98	Macquarie St Hospital hydrant	485	232	Not tested	8	110
98054679	29/07/98	Museum College St hydrant	3150	849	Not tested	135	190
98054684	29/07/98	Crown St. Reservoir	38	24	Not tested	19	36
98054685	29/07/98	Crown St Reservoir	170	0	Not tested	4	1
98054686	29/07/98	50 Llewellyn St Rhodes (slide#3)	35	7	0/4 (0%)	5	1
98054696	29/07/98	Boundary Rd, Oakville hydrant	208	144	Not tested	20	19
98055042	30/07/98	Station St, Tempe	52	3	4/33 (12%)	18	0
98055044	30/07/98	Inlets Potts Hill No1	86	23	Not tested	14	47
98055104	30/07/98	Kembla Grange WFP	52	2	0/45 (0%)	31	1
98055105	30/07/98	64 Buttenshaw Ave, Coledale	21	0	0/14 (0%)	12	0
98055111	30/07/98	Pressure tunnel shaft 6	10	0	0/1	8	0
98055117	30/07/98	Thornleigh res. outlet tap	3	0	0/1	0	0
98055124	30/07/98	Schofields	20	8	1/6 (17%)	5	6
98055252	31/07/98	Prospect WFP filter #1 outlet	1	0	0/1	1	0
98055258	31/07/98	Warragamba 48m	18	5	Not tested	2	1
98055260	31/07/98	Prospect WFP module 3	23	0	0/0	0	0
98055312	31/07/98	Potts pressure tunnel	169	86	12/30 (40%)	Not	tested
98055489	31/07/98	Inlet Pymble Reservoir	11	20	0/3	7	16
98055494	31/07/98	Warragamba pipe No1	93	6	Not tested	5	0
98055499	01/08/98	Inlet pressure tunnel Potts Hill No1	37	0	3/18 (17%)	Not	tested
98058916	13/08/98	Prospect WFP supernatant return	235	2	0/64 (0%)	Not	tested
98059282	14/08/98	Prospect WFP filter 2100 backwash	188	0	0/88 (0%)	Not	tested

* DAPI confirmation undertaken by Thames Water was expected to give a lower count as not all oocysts take up the stain, and some may be lost in the staining process.

I am satisfied that during the First Event both oocysts and cysts were present in drinking waters at levels of public health concern. However, all laboratories reported the presence of algae in the water which could mimic IFA stained parasites, and at times AWT may have misidentified some algae as parasites. However, given the method it was using, which did not include a confirmatory step, results were broadly in line with the "presumptive" numbers reported by Thames Water and Macquarie University. Many of the parasites isolated during the First Event appeared degraded, and unlikely to cause infection. Many of these were empty shells which may have been *Cryptosporidium* although it is possible they were not. A definitive answer to this question cannot be given.

Second Event: 24 August-5 September

In my Second Interim Report, I identified that in the Second Event extremely high levels of organisms had apparently passed through Prospect plant and were measured in the supply system immediately downstream, including one reading in the treatment plant laboratory. This suggested that the cause of the Second Event was likely to have been the inflow of extremely high levels of organisms with rainwaters, which rapidly filled Sydney's catchments. Not only was faecal matter from animals in the catchment likely to have been washed into the reservoirs, but many of the sewage treatment works in the Outer Catchment also overflowed poorly treated sewage into catchment waters.

Confirmation of AWT's analysis was difficult, as only five unprocessed samples and three water sample concentrates containing apparent parasites were available from AWT for examination by the outside laboratories. The US laboratory, however, showed that all of the unprocessed samples (two raw and three filtered waters) were free of parasites.

In particular, two samples of raw water from the Prospect plant (28 August) originally reported to have high numbers (280 and 151 *Cryptosporidium* and 98 and 37 *Giardia* in 10 litres) were found to be negative when re-examined by AWT and the US laboratories. These re-examinations were performed one month after the original analysis and sample deterioration might explain the lower results. However, sample deterioration for *Giardia* was not seen in the same series of samples processed and reported for the First Event.

There are conflicting views on the interpretation of these results. AWT maintains that the data is not valid as the samples were not stored correctly. AWS believes that the data demonstrate that the original results were overestimates. The original slides were re-read by an independent scientist who confirmed that both *Cryptosporidium* and *Giardia* were present on the original slide. Because of the uncertainties related to the survival of the organisms and their identification I cannot determine which interpretation should be accepted.

Further evidence of difficulties comes from the quality control samples. Recoveries of spiked oocysts and cysts from laboratory tap water yielded an unusually low 0.2-0.3% recovery at AWT, 13% and 19% by CEC and 2.6% at CH Diagnostics. AWT's performance procedure recommends recoveries should be over 50%. The lower than expected recoveries of spiked parasites may indicate that the control material had been overestimated. For most samples, AWT reported results that were similar to the US laboratories. Analysis of two samples which had been concentrated by AWT showed that they detected more organisms than the USA laboratories. These results suggest that AWT may have had a problem with their water concentration procedure.

It is possible that organisms were mis-identified as *Cryptosporidium* and *Giardia* by AWT during the initial analysis or that samples could have become contaminated during laboratory examination. However, the fact that AWT results concurred with those from the USA and that slides read earlier by Thames Water indicates that AWT was accurately identifying *Cryptosporidium* and *Giardia*. The large number of positive samples during the Second Event suggests that laboratory cross-contamination was unlikely to have accounted for all of the positive readings. Few of the raw water samples tested positive by FISH, indicating that *Cryptosporidium* may be degraded and non-infectious (Table 2). Data presented by AWS on four samples collected within 30 minutes of AWT's (22 and 28 August) showed zero or counts 99% lower than those reported by AWT for the same raw waters at Prospect plant.

It is not possible at this stage to determine definitively if mis-identification or cross-contamination occurred, but it appears unlikely that the readings were the result of misidentification. Further discussion of both possibilities is discussed in relation to the Third Event.

Table 2 AWT *Cryptosporidium* and *Giardia* counts along with FISH for the Second Event

Sample ID	Sample Date	Location	AWT Result per slide read		FISH test for Crypto.
			Crypto.	Giardia	+ve/total tested
98059282	24/08/98	1 Lawson Rd, Paddington	370	22	0/346
98061384	24/08/98	1 Hospital Rd, Tap	270	39	3/270
98060967	24/08/98	Warragamba 33m	552	11	0/517
98061381	24/08/98	Prospect WFP D/S dist. chamber	72	13	0/64
98061389	24/08/98	118 Pacific Ave, Palm Beach	1050	347	0/932
98061382	24/08/98	Prospect WFP, lab tap	863	252	-
98061756	26/08/98	Warragamba DWA2 21m	287	15	4/44 (9%)
98061928	26/08/98	R209/R304 (M0H1)	114	17	4/19 (21%)
98062185	27/08/98	R129 outlet	1526	227	6/53 (11%)
98062187	27/08/98	Prospect WFP raw water	3020	530	66/100 (66%)
98062189	27/08/98	Prospect WFP lab tap finished water	1889	455	72/100 (72%)
98062282	27/08/98	Broughtons Pass Weir site 1	22	8	6/12 (50%)
98047180	28/08/98	Woronora WFP pre NH_3	1	3	1/1
98062286	28/08/98	Macarthur WFP filtered	24	2	14/16 (87%)
98062092	27/08/98	Prospect WFP finished CWT	1348	467	-
98062091	27/08/98	Prospect WFP lab tap finished	70	9	-
98062188	27/08/98	Prospect WFP channel 2 raw	12080	2120	-
98062189	27/08/98	Prospect WFP lab tap finished	9400	2250	-
98062185	27/08/98	Warragamba WFP treated	1526	227	-
98062344	28/08/98	Prospect WFP finished CWT	5	0	0/5

Third Event: 5 - 19 September

On Saturday 5 September, a boil water notice was issued for the third time for most of Sydney after high numbers were found in the raw and finished water at the Prospect, Warragamba and Orchard Hills plants. Numbers in excess of 500 oocysts and 3,500 cysts per 100 litres were reported in Prospect filtered water (sample #98068786, 4/9/98) when the plant was functioning well for turbidity and particle removal. Hence, parasites in excess of 50,000 oocysts and 350,000 cysts per 100 litres must have arrived in the raw waters if the plant was functioning with 99% removal, or at ten-fold higher numbers if removing 99.9%. Raw water in the pipeline was measured by AWT to have 10,000 oocysts and 7,600 cysts (sample #98068774, 4/9/98) (Table 3).

Such high numbers of parasites in raw waters would normally have been associated with other faecal indicator microorganisms, yet consistently low numbers of faecal indicator bacteria were reported by AWT. A possible explanation is that the source of the faecal material was very old, and faecal indicator bacteria had died out. The low levels of faecal sterols measured (some reported in Table 4) support the possibility of a distant source of faecal contamination.

Of the five samples analysed for faecal sterols and parasites, herbivores were the sole source of faeces contamination identified (Table 4). However, of the 42 samples analysed, unambiguous human faecal contamination was noted twice in Warragamba below the thermocline (#98070786 & 98070695) and twice in Cataract in the surface waters above the thermocline (#98070755 & 98071767) during the Third Event. Only one sample was positive for the human-specific virus (phage) to B. fragilis HSP40 (#98058813 from the Second Event).

Table 3 Results during the Third Event

Sample ID	Sample Date	Location	AWT Result per slide read		FISH test for Crypto
98068412	03/09/98	Prospect Nth run upper comp.	173	121	**33% ? ***
98068774	04/09/98	Warragamba pipeline comp.	502/5L	381/5L	**25% ?**
98068691	04/09/98	Orchard Hills WFP raw	15	0	**16% ?**
98068690	04/09/98	U/canal inlet to channel 2	40/5L	10/5L	**14% ?**
98068742	04/09/98	Warragamba raw water	59/18	37/18	**15% ?**
98068771	04/09/98	Warragamba filtered R129	121	250	**10% ?**
98068789	04/09/98	Longworth Ave, Castle Hill	37/10L	1368/10L	**0% ?**

* % ? means that AWT supplied the percentage FISH positive but not the raw data.

Table 4 Concentration of faecal sterols (ng L-1), abundance of bacterial indicators (cfu/100 ml) and proportion of human, herbivore and other faecal contamination ± the range of likely values based on current data, in water samples from Warragamba (DWA) and Cataract (DCA) Dams

Site →	DWA2 57m	DWA2 30m	DWA1 at Screen 40m	DWA2 at 30m	DWA2 at 27m	DCA1 dam wall 30m
date collected →	13/8	11/9	13/9	13/9	11/9	14/9
indicator ↓ sample no. →	98058813	98070696	98070786	98070783	98070695	98071168
coprostanol	54	ND	2	3	6	1
*epi*coprostanol	ND	ND	6	ND	ND	1
cholesterol	729	207	81	4	105	27
5α-cholestanol	160	TR	4	8	7	2
24-ethylcoprostanol	246	TR	1	10	10	4
24-ethyl-*epi*-coprostanol	107	ND	1	5	ND	1
24-ethylcholesterol	826	76	23	2	39	66
24- ethyl-5α-cholestanol	247	ND	2	23	6	5
5β / 5α coprostanol ratio*	0.34	-	0.44	0.31	0.95	0.48
ethylcop / 24-ethyl-5α-cholestanol*	1.00	-	0.70	0.45	1.69	0.87
thermotolerant coliforms	340	3	0.1	0.1	0.1	4.2
faecal streptococci	-	0.4	0.3	0	0.1	0.1
C. perfringens spores	111	2.2	2.8	1.4	1.3	12
B. fragilis HSP40 phage (in 200mL)	+ve	-ve	-ve	-ve	-ve	-ve
Cryptosporidium oocysts	86/L	143/100L	0/6L	0/20L	Not tested	0/9L
Giardia cysts	10/L	75/100L	0/6L	0/20L	Not tested	0/9L
% human (based on biomarkers ONLY)	0	NQ	61	0	18	0
% herbivore (based on biomarkers ONLY)	100	NQ	39	100	82	100
% human input	-	NQ	81± 2	0	23 ± 2	0
% herbivore input	58 ± 14	NQ	19± 2	100	77 ± 2	88± 18
% other input (eg birds)	42 ± 14	NQ	0	0	0	12± 18

ND: below detection (detection limit 1 ng L^{-1}); TR: trace amounts (,5 ng L^{-1}); NQ: not quantifiable
* ratio over 0.5 indicates unambiguous faecal contamination.

It was even more difficult to explain the consistent findings of high numbers of parasites in the northern region of the Prospect system, with the highest value recorded being 3,700 oocysts and 13,670 cysts at Castle Hill (#98068789, 4/9/98, Table 5).

AWS' analysis during the Third Event was extensive and while parasites were identified in raw waters at similar levels to AWT (in the hundreds to low thousands per 100 litres), none were reported for finished water (Joint Action Group, AWS-CIRSEE Sampling and Analysis Report, 1998).

The methodologies used by AWS and AWT were different and this may have contributed to the differences in the results. In addition, the volume of water examined by AWS for some samples was only one litre. Thus levels of *Cryptosporidium* and *Giardia* would need to exceed 100 per 100 litres to give a positive result.

Other samples analysed by AWS/CIRSEE consisted of 10 - 1,000 litre volumes of water being concentrated using a particular type of filter. I have been advised that these filters are not as efficient at recovering *Cryptosporidium* and *Giardia* from large volumes of water as the method used by AWT, and therefore the sensitivity of the analysis may be lower. I have received data from AWS demonstrating the recovery efficiency of its procedure and while the information is not complete, I am advised that inappropriately high numbers of *Cryptosporidium* and *Giardia* were used to perform these experiments. Hundreds rather than hundreds of thousands of oocysts are required to estimate the efficiency of the method used.

Positive findings were found in seven of Sydney's water filtration plants on 11 September 1998, as well as in Sydney's most protected catchment, Cataract dam. This extraordinary connection of events suggested possible mis-identification (Table 5). However, these slides were read by an independent scientist, regarded as expert in the identification of *Cryptosporidium* and *Giardia* and confirmation was provided using DAPI staining.

Most of the raw water samples taken on the same day were not analysed until 10 days later. There was evidence of *Cryptosporidium* and *Giardia* in the raw water from Warragamba but no evidence of *Cryptosporidium* or *Giardia* in the other samples. Because of the time taken for water to flow through the treatment plant, the raw and filtered water results do not relate to exactly the same body of water. AWT responded by re-sampling the following day, and recorded zero parasites in filtered waters.

AWT also provided evidence that five negative quality control samples were processed by its laboratory, evenly spread throughout the positive samples. All five were shown to be free of parasites. However, I would not exclude the possibility of laboratory contamination giving the positive results.

AWT submits that it is unlikely that the results from the filtered water were all as a result of cross contamination. I am satisfied that there is no positive evidence of cross contamination. However, the results represent an extraordinary coincidence and I believe they are unlikely to be representative of the water being supplied by the treatment plants.

Data used to source faecal contamination (faecal sterols) indicated that some (12-20%) human faecal contamination may have occurred above the thermocline in Cataract dam, but only by herbivores below the thermocline. However, only one sample with predicted positive oocyst-like particles (LIMS No 98070026) was also assayed for faecal sterols. Interestingly, neither herbivore nor human faecal contamination was evident, only cholesterol which may result from algal biomass. Furthermore, attempts to amplify the 18S rDNA from any oocysts within the Cataract sample failed despite a successful PCR reaction for other organisms, supporting the possibility that there were very few or no intact and viable oocysts present.

Overall, the faecal sterol and human-specific virus work indicated predominantly herbivore faecal contamination in the dams. There was also strong evidence for occasional human faecal contamination. It follows that the bulk of the *Cryptosporidium* and *Giardia* detected was likely to have come from catchment animals.

Table 5 Filtration plant and Cataract results for 11 September

LIMS No	Sample Date	Sample Location (20L & 100L raw and filtered waters respectively)	AWT Result per slide read	
Filtration plant samples			***Crypto.***	***Giardia***
98068785	04/09/98	Prospect WFP raw water	0	0
98068786	04/09/98	Prospect WFP finished water (paired result with raw water given above)	>500	>3500
98070627	11/09/98	Woronora WFP raw water (20L)	0	0
98070628	11/09/98	Woronora WFP filtered water	55	61
98070629	11/09/98	Illawarra WFP raw water (20L)	0	0
98070630	11/09/98	Illawarra WFP filtered water	141	107
98070680	11/09/98	Macarthur WFP raw water (20L)	0	0
98070681	11/09/98	Macarthur WFP filtered water	59	52
98070682	11/09/98	Nepean WFP raw water (20L)	0	0
98070683	11/09/98	Nepean WFP filtered water	106	97
98070672	11/09/98	Warragamba pipeline HWP (20L)	33	33
98070675	11/09/98	Warragamba WFP filtered R129	193	214
98070676	11/09/98	Orchard Hills R209/304	268	305
Cataract Dam samples				
98070024	9/09/98	Cataract Dam 10m	14/16L	43/16L
98070025	9/09/98	Cataract Dam 20m	9/8L	20/8L
98070026	9/09/98	Cataract Dam 30m	-	-
98070027	9/09/98	Cataract Dam composite 10-30m	428/8L	137/8L

Mouse infectivity tests

As previously indicated, there has been much discussion in the scientific literature regarding the viability and infectivity of *Cryptosporidium*. If a *Cryptosporidium* oocyst is shown to be empty by DAPI staining, then it must be dead since viable *Cryptosporidium* oocysts should contain four sporozoites. If it is shown to contain sporozoites, it is potentially alive. The situation is further complicated by the fact that DAPI fails to stain all oocysts and it is possible that viable, infectious oocysts may be recorded as being non-viable.

In addition to the FISH tests used at Macquarie University, parasites from the three remaining stored samples of high counts were sent to Arizona for infectivity assessment. Estimated doses of oocysts delivered to individual mice and the results are provided in Table 6. No mouse receiving Sydney parasites became infected, whereas the control samples performed well, indicating that the dose required for about 50% infection with seven-month-old oocysts was about 150.

Nowhere in the world have environmental oocysts been reported to cause infection in mice. While the mice infectivity test is perhaps the only valid measure of potentially human infective oocysts, it is important to note that large numbers of oocysts are required for the test to be sufficiently representative. For example, if the Sydney environmental oocysts were some months old, but preserved to maintain activity, then from the results with stored calf oocysts, one might expect a dose of some 125 oocysts (if 25% of 98068774 were viable) to produce infection in about 10% of inoculated mice. Hence, having material to only inoculate a few mice greatly reduced the probability of demonstrating the presence of infectious oocysts.

Table 6 Results from the mice infectivity tests

Sample ID (FISH positive)	Source	Oocyst Dose	Mice Challenged	Percent Infected
98068774 (25%)	Warragamba pipeline 4/9/98	500	3	0
98061382 (not tested)	Prospect WFP finished water 24/8/98	250	3	0
98061928 (21%)	Orchard Hills R209/304 26/8/98	300	2	0
PC 1*	Calf faeces	600	12	92
PC 2	Calf faeces	300	10	90
PC 3	Calf faeces	150	10	40
PC 4	Calf faeces	50	11	0
NC 1	Bacteria	0	5	0

* PC = positive control oocysts were seven-month-old oocysts harvested from a calf from Camden, Sydney, stored at 4šC and with 69% "viable" with PI.
NC = negative control, containing water bacteria only.

What has been done to check the results?

An initial audit of AWT and Macquarie University laboratories was undertaken in August and followed up in September. The first audit was designed to determine if the methodologies used by the laboratory were appropriate. The audit concluded that the staff understood the scientific methodology they were using and could reliably recognise *Cryptosporidium* and *Giardia*. The audit, however, identified a number of deficiencies at AWT and Macquarie University with regard to the quality control system used by the laboratory. I understand that these are currently being addressed.

The more intensive second audit conducted for AWT focussed on the technical competency of the staff and the laboratory's quality control procedures. Significant deficiencies were noted in both the way that analysts performed their tasks and in the quality control program. It was also noted the laboratory had made no attempt to correct the deficiencies highlighted in the first audit. As such, the auditor concluded that:

- data from the laboratory should not be used to make public health decisions until all deficiencies are corrected and data quality can be assured;
- immediate focus of the laboratory should be on correcting all deficiencies as soon as possible to facilitate this, an external Quality Assurance officer should be appointed to oversee this process;
- the laboratory should participate in an expanded external Quality Assurance scheme which will allow confidence in the data generated; and
- a full audit of the laboratory once all deficiencies have been corrected should be conducted to ascertain that data quality is reliable.

The audit finding and AWT's response

The second audit identified the following deficiencies in the laboratory:

1. serious potential for cross contamination between samples in the laboratory. In fact some "negative control" samples, which were deliberately introduced into the laboratory, produced positive readings;
2. lack of method performance of 85 entries on performance samples examined, 62 (73%) were below the stated 50% recovery and recoveries ranged from 0-133% for *Cryptosporidium* and 0-184% for *Giardia*;

3. LIMS labels incorrectly applied, incomplete and unvalidated data sheets, data crossed out and re-entered without explanation;
4. no validation data for methods used; and
5. deficiencies noted cast doubt on the reliability of data for management decisions.

AWT accepted the first three findings but noted that:

- ● 2% of negative control samples (out of 150) returned positives and these were only of very small counts, and 8.6% positive controls out of 150 gave negative results;
- seed material needs to be evaluated (by flow cytometry) prior to use and a more reliable source of seed needs to be found; and
- a new full-time quality control officer has been found and will start shortly.

Despite the deficiencies in the quality control data, AWT believes that the data were suitable for public health decisions to be made. It submits that it explained to Sydney Water that the large volume of work requested of the laboratory would lead to poorer quality results. It also points out that it could not stop processing samples as this would have led to no data being available to monitor the situation in Sydney's water. AWT has provided evidence which confirms that it told Sydney Water of the problems it was having with quality control data. Sydney Water has confirmed that when Macquarie University was asked to do more work, it replied by saying that it could not as it was having problems with quality control which was leading to problems with the negative controls. Apparently Macquarie University was asked to perform the analyses despite the quality control problems. It is clear that Sydney Water was prepared to accept data for which the quality control was inadequate.

The matters raised in points 1-5 are extremely serious. The findings should have led to immediate and thorough investigations. However, there was no effective response by the laboratory. The auditor's finding that there is no specific quality assurance plan has not been resolved. Complete training of staff will take months.

In response to the auditor's concern about the lack of validation data, AWT said that:

- significant method validation data exist, but are commercial-in-confidence;
- their testing procedure is undergoing constant improvement, with rigorous validation applied at each step; and
- improvements are expected to continue for the next nine months to a year, before seeking formal accreditation with NATA.

The most serious issue which AWT disputed in the auditor's findings was the doubt about the reliability of the data for management decisions. AWT listed the following factors as confirming its data:

- confirmatory slide reading undertaken at Macquarie University and Thames Water;
- inter-laboratory comparisons of concentrated and unconcentrated water samples;
- FISH and RT-PCR testing;
- positive and negative control samples; and
- internal checks, such as process triggers (eg. high positive or low positive/negative after a high positive).

It is my view that the confirmations at Macquarie University and Thames Water were appropriate, but only validated the final step of AWT's method. Furthermore, no action was taken when negative controls were positive, or when performance was below the 50% recovery mark, although it is clear AWT did inform Sydney Water of the problems it was having. The use of untrained staff for a critical step of the process (concentration) without adequate quality control was inappropriate.

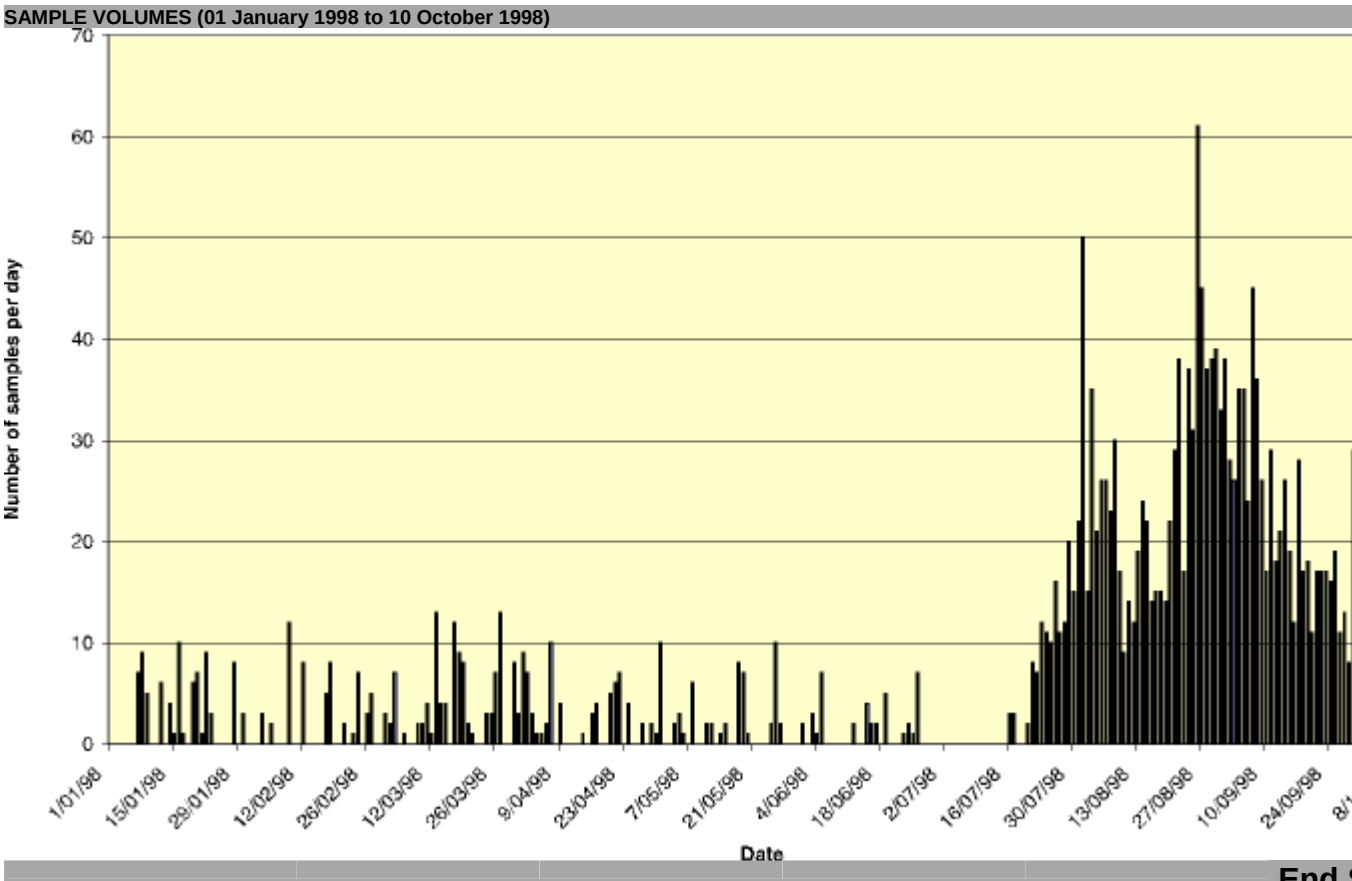
It must be remembered that AWT was resourced to handle 10 samples or less on average per week at the time of the contamination events. Yet during the incident, it was required to handle up to 60 per day. A summary of the number of samples analysed per day and the resources allocated to this is shown on the following page. I have great sympathy for laboratory staff in the demands placed on their resources by the contamination events. Nonetheless, by late August and into September, the quality control in the parasite laboratory had broken down.

Conclusions

There is no general agreement about the quality of the data generated by tests for the detection of *Cryptosporidium* and *Giardia*. Various methods are in use throughout the world and no procedures have been fully validated. There is significant uncertainty regarding their efficiency or reliability. Different laboratory techniques yield different recovery rates. Comparison of the levels recorded in Sydney with those reported from overseas may have limited value. While the techniques used by AWT during recent events have the capability of producing good recoveries, on several occasions poor recoveries were recorded. These difficulties in accurately assessing the numbers of parasites present in water samples lead to uncertainty about the health consequences.

There was definitely *Cryptosporidium* and *Giardia* in raw and treated water though the actual levels recorded are uncertain. Despite these uncertainties, the various public health responses throughout the contamination incidents were appropriate.

Number of samples per day analysed by the AWT laboratory and the resources allocated



STAFF	Jan 1998	End Jul 1998	End Aug 1998	Mid Sep 1998	End 199
Full-time	5	5	10	13	13
Casual	-	-	4	4	4

EQUIPMENT	Jan 1998	21 Aug 1998	27 Aug 1998	18 Sep 1998	25 S 199
Flow cytometer	**1**	**1**	**1**	**2**	**2**
Flat bed filters	**2**	**3**	**3**	**5**	**6**
Microscopes	**2**	**2**	**3**	**3**	**3**

Many oocysts identified during the First Event were degraded and their species could not be determined.

Some of the laboratory results from the Third Event appear to be unreliable and were the least validated by external laboratories.

AWT was under considerable pressure to analyse large numbers of samples. This led to a breakdown of an already poor quality control procedure. Staff with insufficient training and experience were performing analyses. These problems were identified during the second audit of the AWT laboratories.

Because of the uncertainty of the analytical results from AWT and AWS, it is not possible to use this data to meaningfully assess the performance of the filtration plants during the contamination events.

However, AWT has recently produced data which suggests that there is a relationship between the numbers of *Cryptosporidium* in the raw water and the numbers found in the treated water. It has also provided evidence that the numbers found in water leaving Prospect plant are consistent with the numbers found in the distribution system. This is not inconsistent with my conclusions in the Third Report. However, because of the uncertainty in detection, I cannot reach firm conclusions on the performance of the treatment plant. It is clear that when extremely high levels of *Cryptosporidium* and *Giardia* entered the Prospect plant, some were released into the treated water.

I confirm my recommendation that a suitably qualified independent laboratory be established to provide accurate data for health and regulatory authorities.

It will be necessary to identify an appropriate laboratory which must have adequate resources. Whether Government provides it or an existing commercial laboratory is utilised, needs further consideration. This must take place without delay. The AWT laboratory, with adequate training and quality management, should continue to perform analytical work for clients including Sydney Water. It will need the assistance of appropriate external expertise. I do not intend that the independent laboratory should replace AWT although its future role must be considered by the management of both Sydney Water and AWT.

Numbers called 88
Not connected 3
No answer/answer machine 23
Not contacted after 3 attempts 2
Fax 1
Business 4
Non-English speaking 3
Unavailable for duration of survey 1
Refused 16
Away during the exposure period 1
Completed interview 34 Households
Individuals 119
Age (mean ± SD) 34.1 ± 18.0 years
Children <16 years old 25 (21%)
Attend childcare 2
Males 63 (53%)
Females 56 (47%)
Diarrhoea since 4 August 13 (11%)
Diarrhoea today 0
Saw doctor about diarrhoea since 4 August 3 (3%) (1 prescribed Fasigyn & sample taken)
Diarrhoea ≥ 3 BM/day for > 3 days 3 (3%)
Drank unboiled tap water 5-11 September 24 (20%)
Number of glasses per day (Mean ± SD) 2.0 ± 1.16
Diarrhoea since 4 August 2 (10%)
Diarrhoea today 0

Saw doctor about diarrhoea since 4 August 1 (5%)
Diarrhoea ≥ 3 BM/day for > 3 days 1 (5%)
Precautions taken
Boiled drinking water ≥ 1 min 94 (80%)
Boiled drinking water < 1 min 3 (3%)
Drank bottled water 62 (52%)
Brushed teeth in boiled water 64 (54%)
Lived in household where foods were washed in boiled water 83 (70%)

Address	**Date**	**Cryptosporium oocysts**	***Giardia* cysts**
Riley Ave			
West Pennant Hills	4 September 1998	29 per 10 L	30 per 10 L
Longworth Cres			
Castle Hill	4 September 1998	37 per 10 L	1,369 per 10 L
Hunt Ave			
Dural	4 September 1998	5 per 10 L	2 per 10 L
Honeytree Pl			
Baulkham Hills	4 September 1998	0 per 10 L	2 per 10 L
Orange Grove			
Castle Hill	4 September 1998	21 per 10 L	32 per 10 L
Gooden Drive			
Baulkham Hills	7 September 1998	28 per 10 L	39 per 10 L

Item	**Control**	**Exposed**
Households	195	261
Individuals	595	763
Mean age	33.9y	35.9y
Children aged <16 years	157 (26%)	174 (23%)
Attend childcare	14	12
Females	303 (51%)	389 (51%)
Males	283 (48%)	356 (47%)
Sex not reported	8	8

Drink tap water (usually)

Mean No. glasses/day	4.1	5.7
1 glass/day	31	62
2 glasses/day	69	97
3 glasses/day	78	81
4 glasses/day	59	81
5 glasses/day	135	133
Did not state glasses/day	224	309

Diarrhoea since 4 August 98	49 (8%)	104 (13%)
Diarrhoea >3 days definitely	13 (2%)	10 (1%)
Diarrhoea >3 days possibly	22 (4%)	28 (4%)
Diarrhoea on interview day	14 (2%)	16 (2%)
Saw Doctor about diarrhoea since 4 August 98	15 (3%)	25 (3%)

Effect of boil water order

Boiled drinking water > 1 min 655 (86%)
Boiled drinking water < 1 min 32 (4%)
Drank unboiled tap water 96 (13%)
Drank bottled water 368 (48%)
Brushed teeth with boiled water 296 (58%)
Lived in household where foods
were washed in boiled water 461 (60%)

Item	Control	Exposed
Households	173	163
Individuals	520	503
Mean age	33.7y	37.3y
Children aged <16 years	145 (28%)	98 (20%)
Attend childcare	20	11
Females	264 (51%)	258 (51%)
Males	253 (49%)	238 (47%)
Sex not reported	3	7
Drink tap water (usually)	439	438
Mean No. glasses/day	3.7	3.9
1 glass/day	34	4
2 glasses/day	109	24
3 glasses/day	70	81
4 glasses/day	73	86
5 glasses/day	140	117
Did not state glasses/day	23	38
Diarrhoea since 1 July 98	56 (11%)	50 (10%)
Diarrhoea >3 days definitely	10 (2%)	9 (2%)
Diarrhoea >3 days possibly	18 (3%)	16 (3%)
Diarrhoea on interview day	11 (2%)	8 (2%)
Saw Doctor about diarrhoea since 1 July 98	13	7

Effect of boil water order
Boiled drinking water > 1 min 382 (74%)
Boiled drinking water < 1 min 40 (8%)
Drank unboiled tap water 35 (7%)
Drank bottled water 207 (40%)
Brushed teeth with boiled water 314 (60%)
Lived in household where foods
were washed in boiled water 289 (55%)

Week	Faeces[#]	Cryptosporidiosis^	*Giardia*sis^
5-11/7	822	0	2
12-18/7	805	1	0
19-25/7	927	2	3
26/7-1/8	1,636	2	13
2-8/8	2,253	0	26
9-15/8	Incomplete*	0	12
16-22/8	NES	0	16
23-29/8	Incomplete**	1	11

30/85/9	1,752	0	1	
6/9-12/9	1,885	0	0	

Year	Country	No. of people affected	Oocysts detected in implicated water supply	Postulated reasons for outbreak occurring
1990	UK (N. Humberside)	447	Oocysts detected in untreated and treated water	Bypassing of slow sand filters
1990	UK (Isle of Thanet)	>47	None detected	Unknown
1991	USA (Berks County, Pennsylvania)	551	Oocysts detected in untreated but not treated water	Chlorination as sole disinfectant for 'on site' well at picnic site
1992	USA (Jackson County, Oregon)	15,000	Oocysts detected in untreated spring water initially, but not in chlorinated water	Chlorination as sole disinfectant for spring water source
1992	UK (Warrington)	47	None detected	Surface contamination of borehole from agricultural land during heavy rainfall: deficiencies in monitoring of water supply
1992	UK (Bradford, Yorkshire)	125	Oocysts detected at 28 per 100L in untreated, 1 to 18 per 100L in treated and 3 per 100L in distribution waters	Heavy rainfall in catchment area of the untreated water reservoir immediately prior to probable time of infection
1993	UK (Poole, Dorset)	40	Sporadic low levels of oocysts detected in service reservoir but not in settled silt	No likely mechanism for contamination of borehole water supply identified
1993	USA (Milwaukee, Wisconsin)	403,000	Oocysts detected in ice made at the time of the outbreak at densities of up to 13 per 100L	Possible contamination from either sewage, agricultural waste or slaughterhouse effluent
1993	USA (Yakima County, Washington)	3	Oocysts detected in well water	Melting snow and spring rains containing faeces (cattle, sheep, elk) contaminated well water
1994	USA (Clark County, Las Vegas)	78	Not determined	No identifiable treatment deficiency
1994	USA (Walla Walla County, Washington)	86	Not determined	Seepage of treated wastewater into untreated/chlorinated well water
1994	Japan (Kanagawa Prefecture)	461	Not stated	Post-treatment contamination of municipal drinking water caused by cross-connection following malfunction of wastewater pump in private building
1995	USA (Alachua	72	Oocysts detected at the	Inadequate backflow prevention

	County, Florida)		tap	allowing wastewater from garbage can water to enter the camp kitchen's potable water distribution system
1995	UK (Torbay area, Devon)	575	Oocysts detected in untreated and treated water	Under investigation
1996	Japan (Saitama Prefecture)	8,705	Oocysts detected in untreated and treated water	Under investigation

Year	Country	No. of people affected	Oocysts detected in implicated water supply	Postulated reasons for outbreak occurring
1984	USA (Bear County, Texas)	79	None detected	Sewage contamination of well water
1987	USA (Carroll County, Georgia)	13,000	Oocysts detected in untreated and treated water at densities of up to 220 per 100 litres(L)	Faults in operational procedures
1988	UK (Ayrshire, Scotland)	27	4 to 480 oocysts per 100L of treated water	Post-treatment contamination: slurry contamination of water pipe line
1989	UK (Swindon and Oxford)	>515	Oocysts detected in treated water densities from 0.2 to 7,700 per 100L	Possible contamination of untreated water by cattle slurry/muck

Year	Month	Children <15 y	NSW residents
1996	November	2	2
	December	20	21
1997	January	5	11
	February	14	15
	March	6	7
	April	7	8
	May	4	4
	June	5	5
	July	1	3
	August	2	3
	September	1	2
	October	3	4
	November	20	24
	December	63	73
1998	January	98	125
	February	249	352
	March	290	404
	April	81	113
	May	18	41
	June	11	14
	July	8	12

Chapter 9: Public health impacts

A number of issues have been considered when developing recommendations on the appropriate public health response to future contamination incidents. These include:

- the possible health effects of *Cryptosporidium* and *Giardia*;
- the magnitude of risk of *Cryptosporidium* and *Giardia* in drinking water for the general population and the immuno-compromised population;
- the health effects of the recent contamination incidents in Sydney;
- overseas experience in waterborne outbreaks of disease and international best practice in public health response; and
- clinical studies on infectivity of *Cryptosporidium* and *Giardia*.

Possible health effects of *Cryptosporidium* and *Giardia*

How do *Cryptosporidium* and *Giardia* cause disease in humans?

Cryptosporidium and *Giardia* are protozoan parasites which can cause disease in humans. They reproduce in the gut of animals and are shed as oocysts or cysts in faeces as part of their life cycle. People may be exposed to *Cryptosporidium* or *Giardia* if they come into contact with faecal material containing these parasites. Transmission can occur by a number of routes, including person to person (especially in childcare facilities), food or beverages, contact with animals, contamination of swimming pools with faecal material and carriage in drinking water.

Cryptosporidium and *Giardia* can cause gastroenteritis, presenting as diarrhoea and other gastrointestinal symptoms. *Cryptosporidium* may cause prolonged and sometimes intractable diarrhoea in highly immuno-compromised people. In some circumstances it may result in death.

What diseases do they cause?

Gastroenteritis

Gastroenteritis describes an inflammation of the lining of the intestine. This condition may be caused by non-infectious factors or by infection by harmful microorganisms, including but not limited to *Cryptosporidium* and *Giardia*. Gastroenteritis can result in significant loss of fluid and electrolytes (body salts) and can interfere with the absorption of nutrients. There are many different causes of infectious gastroenteritis, which include a range of viruses, bacteria and protozoa such as *Cryptosporidium* and *Giardia*.

Risk of infection

The number of microorganisms required to cause infection varies greatly, depending both on the characteristics of the particular strain of microorganism and on the characteristics of the individual. Ingestion of pathogenic microorganisms, such as *Cryptosporidium* and *Giardia* may result in one of three outcomes:

- passage of the microorganisms through the gut without establishment of an infection or production of symptoms;
- establishment of an infection which does not cause symptoms of illness; and
- establishment of an infection which causes symptoms of illness.

Studies of a range of microorganisms with human volunteers show that the risk of infection increases as the ingested number of organisms increases. However, once infected the probability of developing symptoms does not necessarily vary with the number of organisms ingested, but may depend on the particular strain of microorganism. For some strains most infected people will become ill, while for others only a small minority of infected people will become ill.

Symptoms of gastroenteritis

The symptoms of gastroenteritis that are caused by any of these microorganisms are very similar and commonly include nausea, vomiting, diarrhoea and abdominal pain. The symptoms caused by all the different organisms are so similar that it is very difficult, if not impossible, to distinguish on the basis of symptoms which organism is responsible for an individual's episode of gastroenteritis.

Making a diagnosis of gastroenteritis

The cause of an episode of gastroenteritis is usually determined by obtaining a faecal sample. The sample is examined under a microscope and/or the organisms are cultured to determine the presence of any pathogenic organisms that may have caused the episode. It is not cost effective to test each faecal sample for all possible organisms because some causes are rare and other organisms are very expensive to detect.

In practice, there is considerable variation in the classes of microorganisms that are tested. Most commonly, tests are done for bacterial pathogens such as Salmonella, Shigella and Campylobacter, but tests for viruses and protozoa are less commonly performed. For any faecal specimen submitted, the tests will depend on the request by the physician ordering the test, the interpretation of this request by the laboratory, and the policy of the laboratory.

The causes of gastroenteritis

Only about 30% of individuals with gastroenteritis who submit a faecal sample to the laboratory have a pathogenic microorganism identified. Of these, the most common organism that causes gastroenteritis is Campylobacter which usually causes about 5% of cases, although Salmonella, which causes about 1-5%, and *Giardia* which causes between 2-4% are also among the more common causes. Viruses are also a common cause of gastroenteritis, but are not routinely tested for at present.

***Giardia*sis**

Giardia is one of the most common causes of gastroenteritis. It may be transmitted by direct exposure to faecal material, through person-to-person contact. *Giardia* infection may also be acquired by ingesting contaminated water or food. Transmission to humans from mammals, such as cows, is believed possible although this has not been well documented. It is believed that transmission to humans from other classes of animal, such as birds and reptiles, is extremely unlikely.

Clinical features

The symptoms experienced by someone who contracts *Giardia*sis are variable and generally appear about one to two weeks after infection. A significant proportion of individuals who are infected will develop no symptoms at all, although this is hard to estimate because these individuals never go to a doctor to have a faecal sample taken.

Of those who experience symptoms, most have a mild disease that is resolved without treatment and therefore they never come to the attention of medical practitioners.

Possibly about 10% of those infected may have a prolonged illness that may last for weeks or in some cases longer.

Among those with symptoms who also seek medical attention, the frequency of the individual symptoms are; diarrhoea (64-100%), malaise (72-97%), flatulence (35-97%), foul smelling stools (57-79%), abdominal cramps (44-85%), nausea (59-79%), anorexia (41-82%), weight loss (56-73%), vomiting (17-36%) and, less commonly fever (0-21%).

Asymptomatic carriage

Individuals may be infected with *Giardia* for prolonged periods without any symptoms. This is particularly common in children and is likely to play a part in the fact that this infection is especially prevalent in childcare facilities. The vast majority of infected children are not adversely affected.

Immuno-compromised patients

Individuals with rare deficiencies in their immune symptoms are predisposed to more severe infection with *Giardia* that may be prolonged. Patients with prior gastric surgery, such as partial or total removal of the stomach, may be more susceptible to *Giardia*sis but it is not more severe. Patients with acquired immunodeficiency syndrome (AIDS) do not appear to have more severe illness with *Giardia* than those with healthy immune systems.

Diagnosis

Shedding of *Giardia* in faeces may be intermittent during infection, and testing methods are not sufficiently sensitive to detect low numbers of cysts. To maximise the chance of diagnosis it is recommended three faecal samples be collected and provided to a laboratory for analysis under a microscope. About 90% of cases of *Giardia*sis can be diagnosed in this manner.

Treatment

There is an effective antibiotic for *Giardia*sis that will cure about 90% of cases with a single treatment.

Cryptosporidiosis

Cryptosporidium is generally a less common cause of gastroenteritis than *Giardia* in Australia, except during swimming pool outbreaks when the number of cases caused by *Cryptosporidium* may exceed those caused by *Giardia*. It may be transmitted by direct exposure to faecal material, through person-to-person contact. It may also be acquired by ingesting contaminated drinking water or food. Accidental ingestion of faecally contaminated water in swimming pools is recognised as a common cause of outbreaks. Transmission from farm animals to humans is well documented, and other mammals may also be sources of infection. It is believed that transmission to humans from other classes of animal, such as birds and reptiles, is extremely unlikely.

Children are more commonly affected than adults. Symptoms usually occur within 7-10 days after infection.

Clinical features in those with normal immunity

Some individuals who become infected develop no symptoms. Of those who experience symptoms, diarrhoea is the most common (over 90%); abdominal pain, general malaise, weakness, fatigue, loss of appetite are also common (about 70%); and nausea and vomiting may also occur (about 20%).

Symptoms are generally mild and in most cases subside in less than seven days. Occasionally symptoms may last for weeks.

Immuno-compromised patients

Cryptosporidiosis in highly immuno-compromised people can be severe. People with HIV infection who also have a severely depressed CD4 lymphocytes count experience chronic severe diarrhoea with

profound weight loss. In people with AIDS, cryptosporidiosis can substantially shorten life expectancy. Cryptosporidiosis is less severe in people with less marked forms of immunosuppression such as those on cancer chemotherapy but it is generally more severe than in people with normal immunity.

Evidence from the Milwaukee, USA outbreak indicates that people with HIV/AIDS were not at higher risk of becoming ill, but were at more risk of suffering prolonged illness (MacKenzie et al, 1995). This suggests the number of *Cryptosporidium* oocysts required to establish infection in people with HIV/AIDS is similar to the general population. However, the inability of the immune system to combat the infection leads to chronic illness in those with severely depressed CD4 lymphocytes counts.

Diagnosis

The faeces must be examined using a special stain to diagnose cryptosporidiosis. This is not routinely performed in all laboratories unless it is specifically requested. As with *Giardia*, shedding of organisms in the faeces may be intermittent, and three specimens should be tested to maximise the chance of diagnosis.

Treatment

There is no effective treatment for this infection. However, most cases of cryptosporidiosis resolve satisfactorily unless the immune system is suppressed or deficient.

The incidence of disease due to *Cryptosporidium* and *Giardia*

Both *Cryptosporidium* and *Giardia* infections are relatively common causes of gastroenteritis throughout Australia. Individuals with normal immune systems generally experience mild symptoms and recover fully from both infections.

Young children are most likely to be diagnosed with these infections, suggesting that person-to-person transmission is the most common cause of infection, likely in childcare centres and swimming pools. A more even distribution across the population would be expected from waterborne transmission. There has not been an outbreak of either infection linked to the mains water supply in an Australian capital city.

Cryptosporidiosis has been a notifiable disease in NSW under the Public Health Act 1991 since November 1996. Laboratories detecting the disease are required to notify NSW Health for the purposes of health surveillance, the detection of outbreaks, and to allow an appropriate public health response. Background levels of cryptosporidiosis in the community vary seasonally, with particularly marked variations during swimming pool outbreaks.

In the mid 1990s, a large outbreak of cryptosporidiosis was linked to contaminated swimming pools in Sydney, and in 1997-1998 several more large outbreaks on the east coast of NSW, including Sydney, were traced to multiple contaminated swimming pools. In 1997 there were 159 cases of cryptosporidiosis notified in NSW and in 1998 (to end of September) there were 1,085 cases notified. Table 1 indicates notified cases of cryptosporidiosis in NSW from November 1996 to September 1998.

Table 1
Notified cases of cryptosporidiosis by date of onset (or by date of specimen when date of onset was not reported) in New South Wales.

During the period December 1997 to April 1998, laboratories confirmed 1,067 cases. The majority of these cases were children under 15 years and an association was found between swimming in public pools and infection.

The National Centre for HIV Epidemiology and Clinical Research in Sydney has collaborated in several studies on the incidence of cryptosporidiosis in Australian HIV patients.

Examination of surveillance data on all AIDS patients in Australia indicates a steady decline in persons diagnosed with cryptosporidiosis as an AIDS defining illness: from 40 (4% of all cases) in 1994, 26 (3%) in 1995, 19 (3%) in 1996 and 6 (2%) in 1997. This decline may be due to new antiviral drugs that boost patients' immune response.

In addition, the Centre has collaborated in follow-up studies of patients with AIDS diagnosed up to 1994 to determine the proportion who have ever been diagnosed with cryptosporidiosis. This study found that 8% to 9 % of AIDS patients in Sydney and elsewhere developed cryptosporidiosis at some stage. This study is currently being repeated to examine cryptosporidiosis among AIDS patients diagnosed from 1995 to 1998.

*Giardia*sis was not a notifiable disease in NSW at the time of the contamination events although the Government passed the Public Health Amendment (Scheduled Medical Condition) Regulation 1998 on 25 September 1998 to make a number of diseases, including *Giardia*sis, notifiable for the first time. Monitoring of stool specimens submitted to major pathology laboratories identified 752 positive cases in 1996, 643 in 1997 and 373 to September 1998. The disease is likely to be significantly under-reported as most cases are treated without diagnostic testing.

Cryptosporidium **and** ***Giardia*** **in drinking water**

Cryptosporidium has been isolated from treated and untreated water supplies, swimming pools, rivers, streams, boreholes, spring water and reservoirs in Australia, the USA, Canada, South America and Europe, including the UK.

Surveys in North America have shown that oocysts are widely distributed in the environment. *Cryptosporidium* has been detected in 87% of raw water samples, with *Giardia* cysts detected in 81% of samples. Studies in North America have found *Cryptosporidium* in at least 26% and *Giardia* in at least 17% of public water supplies (Le Chevallier et al, 1991). A number of barriers to drinking water contamination may be present in major community drinking water supplies. These include catchment protection to prevent entry of the organisms into raw water, pre-treatment by detention in protected water storages, water treatment processes (coagulation, settling and filtration), disinfection, and protection of the distribution system from subsequent contamination.

Chlorination can inactivate *Giardia* but contact times need to be one hour for 1.5 mg/L (ppm) of chlorine for water at 15 degrees Celsius. Chlorination disinfection techniques do not kill *Cryptosporidium* oocysts and, because of their small size, even the best filtration techniques may still allow some oocysts to pass into the treated water supply. Health risks associated with the consumption of public drinking water supplies contaminated with small numbers of oocysts have not been authoritatively determined.

Overseas outbreaks related to drinking water

Massive outbreaks of both cryptosporidiosis and *Giardia*sis have been linked to contaminated drinking water systems in recent years in both Europe and North America.

Reported recent outbreaks of cryptosporidiosis due to contaminated municipal drinking water supplies include:

- 13,000 people in Carrollton, Georgia, USA in 1987, due to suboptimal filtration of drinking water;
- 15,000 cases in Jackson county, Oregon, USA in 1992 due to water treatment failures;

- 403,000 cases among the 1.6 million persons in Milwaukee, Wisconsin, USA, in 1993 due to failure of effective filtration;
- deaths of at least 20 persons with HIV infection in Las Vegas, USA, in 1994 (served by a state-of-the-art water treatment plant).

Reported outbreaks of *Giardia*sis due to contaminated municipal drinking water supplies include:

- 5,300 cases in Rome, New York in 1975;
- 3,800 cases in Pittsfield, Massachusetts, population 50,000, in 1985-86 in chlorinated but unfiltered water supply;
- from 1965-1984, 90 outbreaks of 23,776 cases of Giardiasis were reported in the United States, of which 69% of the outbreaks and 74% of the cases were linked to contaminated public water supplies, mostly from surface water supplies with inadequate filtration or chlorination;
- in 1993-94, five outbreaks of Giardiasis were reported in the USA, linked to community drinking water, and affecting 385 persons.

Table 2
Outbreaks of waterborne cryptosporidiosis

(Smith and Rose, 1998)
Note: all measurements adjusted to 100 litres

Health risks posed by *Cryptosporidium* and *Giardia*

Uncertainty about health risks

Despite various outbreaks overseas, the relationship between levels of these parasites in drinking water supplies and public health is currently unclear. *Cryptosporidium* and *Giardia* have been found in drinking water supplies without any evidence that they affect health in humans. However, large outbreaks of disease have been related to the presence of these parasites in drinking water.

Current technologies to distinguish between infective and harmless organisms may be useful but are not believed to be authoritative.

Factors influencing infectivity

Known factors that may influence the infectivity of *Cryptosporidium* and *Giardia* to humans include:

- source (human or animal);
- species/strain;
- viability;
- concentration, ie. levels per 100L of water; and
- immunity, including pre-exposure and individual factors.

Source

Both *Cryptosporidium* and *Giardia* can come from different sources. While both humans and animals may contain organisms which can cause disease, human sources have a higher probability of containing *Cryptosporidium* and *Giardia* which are infectious to humans.

Species/strain

There are a number of species of *Cryptosporidium*. Of these, only C. parvum has been identified as causing disease in humans. Molecular studies on C. parvum have identified different strains or genotypes which vary in their virulence and infectivity to humans. However, neither the techniques for determining species, nor those for genotyping are validated and they are certainly not immediately applicable to environmental samples. Accordingly, when examining water samples for the presence of *Cryptosporidium*, a positive finding must be interpreted with caution since it will not be clear if the organisms are infectious to humans.

Giardia intestinalis, also known as *Giardia* duodenalis or *Giardia* lamblia, is the species of *Giardia* infective to humans. Other species exist which do not appear to infect humans, and these can often be identified by size and shape. It is likely that there is variation between the ability of different strains of *Giardia* intestinalis to cause disease in humans, although there is little scientific evidence to support this (McRoberts, et al 1992).

Viability

The viability of the organism refers to whether it is dead or alive. Only live *Cryptosporidium* oocysts or *Giardia* cysts may be infectious to humans. C. parvum survives up to a year in water and is resistant to chlorination. *Giardia* intestinalis, on the other hand, has a shorter lifespan and cysts are killed by chlorination under the right conditions.

At present there is no reliable method for determining viability for either *Cryptosporidium* or *Giardia*, but there is intensive research in this area. Several methods are showing promise.

To assist in determining the viability and infectivity of the *Cryptosporidium* oocysts found in Sydney water during the contamination episode, mice infectivity studies were conducted. Mice were fed samples of Sydney water containing up to 500 *Cryptosporidium* oocysts. Positive and negative control samples were also administered to provide a baseline to illustrate the infectivity of the Sydney water samples. The study showed that only mice fed with positive control samples were infected, indicating that the *Cryptosporidium* in the Sydney water samples were not infectious at the levels present. However, the exact correlation between infectivity for mice and infectivity for humans is unknown. Further detail on the mice infectivity studies is in Chapter 8.

Concentration/levels

Research to date has failed to show a direct relationship between levels of *Cryptosporidium* and *Giardia* found in drinking water and infection in humans. However, this is most likely due to the mediating effect of other factors such as species/strain, viability and individual immunity. Clinical studies with volunteers have shown increasing levels of infection with increasing doses of the organisms, although one organism alone may cause infection (Dupont et al, 1995). However, there is no agreement on the level of an infectious dose.

The outbreaks of waterborne cryptosporidiosis shown in Table 2 were associated with water supplies containing from 0.2 to 7,700 oocysts per 100 litres. The worst outbreak occurred in Milwaukee and involved reported levels of only 13 oocysts per 100 litres, although this result came from ice made during the event. Unlike the current event in Sydney, in nearly every case waters were not sampled at the time oocysts may have been present. In addition to the influence of species, viability and immunity factors, failure to show a direct relationship between levels and illness may also be due to insensitive monitoring regimes or detection methodologies.

Clinical studies confirm the inconclusiveness of levels alone in determining infectivity:

- a human volunteer study showed that levels of 132 live *Cryptosporidium* would cause disease in 50% of healthy adults (Dupont et al, 1995);
- a United States clinical study showed that the dose of C. parvum necessary to cause infection in 50% of volunteers varied with strain and ranged from approximately 10 to 1,500 oocysts. The onset, duration and severity of illness did not differ among infected individuals (Chappell, 1998).

Immunity

A major issue to consider in assessing health risks posed by *Cryptosporidium* and *Giardia* is the role of protective immunity (Craun et al, 1998). Protective immunity is suggested by information from waterborne outbreaks. Craun et al suggest that immunity may be acquired through low-level sporadic exposure to the organisms in drinking water, which would explain the lack of a direct relationship between levels of oocysts found and illness.

Further evidence of the role of protective immunity was shown in a study that readministered a group of volunteers with the same strain of C. parvum a year later (Okhuysen et al, 1998). The study showed an illness attack rate similar to the first time, however the severity of illness and the number of volunteers shedding oocysts were significantly reduced. Protective immunity was studied in 17 volunteers who had high levels of serum (Moss et al, 1998). In this group, both infection and illness were correlated with dosage levels exceeding 5,000 oocysts in the second study, compared to 10 to 1,500 in the first study.

Conclusions

There is uncertainty about the health risks associated with the consumption of drinking water containing *Cryptosporidium* and *Giardia*.

There are no definitive findings on the concentration of *Cryptosporidium* and *Giardia* in drinking water likely to cause illness in humans.

Infectivity to humans of *Cryptosporidium* and *Giardia* in drinking water is dependent on:

- source;
- species and/or strain;
- viability of organisms (including whether *Giardia* has been killed by chlorine);
- concentration or level; and
- immunity pre-exposure and individual factors.

How *Cryptosporidium* and *Giardia* in drinking water rate as health risks

Both cryptosporidiosis and *Giardia*sis are diarrhoeal illnesses. Although diarrhoea may be perceived as a relatively minor illness for individuals, its public health impact should not be underestimated. These illnesses can have serious consequences for young children, the aged and those with immunosuppression, including those suffering from HIV/AIDS or undergoing cancer treatment. In large-scale outbreaks such as might occur in a drinking water contamination, large numbers of people may require admission to hospital and in some cases there is a significant increase in mortality in the immuno-compromised population. The highest attack rates occur in institutional settings such as childcare facilities, schools and nursing homes where there are concentrations of vulnerable populations. Diarrhoeal disease also causes considerable lost productivity and consequently has a major economic effect on the community.

However, in the general population diarrhoeal illnesses are usually relatively minor when compared with major health risks such as heart disease, cancer and strokes. These illnesses and motor accidents are the major causes of death in Australia. Heart disease alone accounts for more than 10,000 deaths in NSW each year (NSW Health, 1997).

In contrast, compared with many developing countries, diarrhoeal illnesses are not usually a life-threatening problem and do not rank among the top causes of serious suffering in the general population. Diarrhoeal illnesses caused by drinking water are less significant in terms of overall public health effects than those caused by other means, for example, food contamination and person-to-person transmission.

What do we know about the health effects of the recent contamination events?

Results of NSW Health's surveillance program

Background

Following the detection of *Cryptosporidium* and *Giardia* parasites in Sydney drinking water, NSW Health initiated a series of measures to assess the impact of the contaminated water on the community. The approach to enhanced surveillance uses three different methods involving notifications, special surveys, and analysis of results of ongoing surveillance.

It must be recognised that while the results of the surveillance programs are useful, there are limitations in their ability to establish the incidence of disease. Apart from telephone surveys, which were restricted in their coverage, the measures relied on affected persons reporting illness to doctors or other medical personnel. It is possible that a number of people experiencing illness did not report it. On the other hand, over-reporting may also have occurred as a result of increased awareness of the possibility of waterborne illness.

Difficulties in planning a sensitive surveillance system for illness caused by *Cryptosporidium* or *Giardia* include the following:

- diarrhoea is a seasonally common illness in the community and in only a minority of cases is the cause tested for and found there are no clear clinical criteria that separate illness due to *Cryptosporidium* or *Giardia* from illness caused by other intestinal organisms;
- there are background rates of both cryptosporidiosis and *Giardia*sis which are probably unrelated to drinking water cryptosporidiosis is a seasonal illness and both diseases are more commonly acquired by person-to-person transmission;
- cryptosporidiosis is a laboratory notifiable disease, so all cases of laboratory confirmed disease should already be reported. In the recent *Cryptosporidium* epidemic associated with swimming pools, laboratory notification gave the first indication of a problem. However, *Giardia*sis was not notifiable in NSW at the time of the contamination events and rates usually vary considerably week by week. It is therefore difficult both to identify an increase in infection and to be sure it represents an outbreak rather than normal variation;
- while immuno-compromised individuals develop more severe illness from *Cryptosporidium*, current scientific evidence suggests they are no more likely to be infected than non-immuno-compromised individuals consequently rates in immuno-compromised individuals are not likely to be a good indicator of community risk;
- population surveys have the advantage of detection of non-reported illness. However, as indicated above, this is not an indicator of *Cryptosporidium* or *Giardia* per se. A population survey cannot rule out the presence of some disease due to the organisms. At best it can rule out large effects of community exposure that is likely to be seen in waterborne epidemics.

Enhanced surveillance

Beginning 3 August 1998, NSW Health initiated surveillance for diarrhoea in general, and cryptosporidiosis and *Giardia*sis in particular, by asking the six public health units in Sydney to regularly call selected laboratories, general practitioners, emergency departments, pharmacies and nursing homes to ask whether they had observed any increase in cases of diarrhoeal illness. Under the Public Health Act 1991, NSW laboratories are required to notify cases of cryptosporidiosis to public health units. Since 25 September 1998 NSW laboratories are also required to notify cases of *Giardia*sis.

Methods

Each working day, microbiological laboratories were asked to report the total number of stool specimens received for microbiological examination and reports of *Giardia*sis and cryptosporidiosis cases they had diagnosed. General practitioners, emergency departments and chemists were asked to report their impressions of whether there had been any change in the rate of patients with diarrhoea.

Nursing homes were asked to report the number of residents who suffered diarrhoea. Daily surveillance continued from 3 August until 12 August, and resumed on 27 August following the subsequent boil water alert.

Public health units were asked to report to NSW Health central office at the end of each day a summary of their findings, and to enter onto the Notifiable Diseases Database, which is collated centrally, any cases of *Giardia*sis and cryptosporidiosis in Sydney.

Results

Apart from expected day-to-day variations in reports of diarrhoea, most likely representing background rates, there was a mild increase in reports of *Giardia*sis in Sydney residents in early August, as shown in Table 3. At the same time there has been no significant increase and very few reports of cryptosporidiosis in Sydney residents.

There have been no reports of major or sudden increases in the number of attendances for the management of diarrhoea by selected emergency departments, general practices, and chemists.

One nursing home in the eastern suburbs reported an outbreak of diarrhoea affecting about 20 of the 100 residents over the period 13-28 August 1998. All patients have recovered. The illness was of short duration. The staff assessed that the diarrhoea was probably due to a gastrointestinal virus. No other nursing homes reported outbreaks of diarrhoeal illnesses.

Table 3
Reports of cryptosporidiosis and *Giardia*sis, by specimen date, Sydney, July-September 1998

Number of faeces samples submitted for microbiological examination each week. Complete data for the entire period available from three Area Health Services (Northern Sydney, South Eastern Sydney and Western Sydney. Participating laboratories: Douglass Hanley Moir, General Clinical Laboratories, Sydney Diagnostic Service, PALMS, St Vincent's Hospital, Mansfield Pathology, Davies Campbell De Lambert, Quinn Pathology, Endemic Pathology, SEALS, ICPMR, New Children's Hospital, Hampson's Pathology).
^ Notifications from Sydney Metropolitan Area Health Services.
NES No enhanced surveillance (for 13-26 August).
* Data available for 9-12 August only (N= 822).
** Data available for 27-29 August only (N=873).

Discussion

Data from the enhanced surveillance does not suggest any increase in diarrhoeal illness in the Sydney area. The small non-significant increase in *Giardia*sis is likely to be attributable to increased testing and identification of background cases unrelated to drinking Sydney water. This is supported by data available to the South-Eastern Sydney Public Health Unit showing that laboratory isolation of other

non-water related gastrointestinal pathogens, particularly Campylobacters, increased in the same period as *Giardia* increased.

Household surveys

Household survey number 1 First Event

To determine the effect of the public health alert on Sydney residents and to help early identification of a large outbreak of waterborne diarrhoea, NSW Health initiated a household survey in August. This survey was designed to record health effects due to contamination between the likely first contamination event on 21 July up to the boil water alert on 29 July, including the incidence of diarrhoeal illness in the community and compliance with the boil water alert.

Methods

The method used was a telephone survey of households listed in the White Pages. The survey covered 503 persons in 163 households in areas of Sydney affected by the boil water alert, and 520 persons in 173 households in areas unaffected by the alert. The survey began on 5 August, allowing an incubation period of about seven days after 29 July for illness to have developed. However, it is unlikely that there would have been enough time for illness to have developed in people who continued to drink unboiled tap water after 29 July.

NSW Health considered diarrhoea lasting more than three days most likely to represent infection with the parasites *Cryptosporidium* and *Giardia*, since these infections typically cause longer-lasting illness than many other pathogens. Reported diarrhoea of shorter duration is considered likely to be due to other factors, including viral infections, and is more prone to reporting bias.

The size of the survey can reliably rule out a doubling of the incidence of illness from 2% to 4% between exposed and unexposed groups in the community or between successive surveys.

Results

Preliminary analysis shows that in both affected and unaffected households, approximately 2-3% of persons reported diarrhoea lasting more than three days in the previous month, and 2% of persons reported diarrhoea on the day of the survey. Households in affected and unaffected areas reported similar rates of diarrhoea of any duration in the previous month, 10-11%. See Table 4.

Discussion

The first household survey, after the first contamination event, did not detect any increase in disease likely to be attributable to drinking Sydney water. Diarrhoea in Sydney appears to run at about 10%.

Table 4
Household survey 1. Characteristics and responses of persons in Sydney, The Blue Mountains, The Hunter, and Illawarra areas 5-8 August 1998 (preliminary analysis).

Household survey number 2 Second Event

Following the second boil water alert, starting on 24 August, NSW Health began a second survey of households in affected and unaffected areas on 4 September to determine the effect of the public health alerts, and to search for evidence of a large increase in diarrhoea that might be attributable to drinking contaminated Sydney water.

Methods

This survey was expanded to include an extra 80 households in the Nepean and lower Blue Mountains areas because of the possibility that these residents were more likely to have been exposed to contaminated water before the second boil water alert was extended to those areas on 27 August.

The survey covered 763 persons in 261 households in areas of Sydney affected by the boil water alert, and 595 persons in 195 households in areas unaffected by the alert. The survey began 4 September and lasted until 8 September.

Results

Preliminary analysis shows that in both affected and unaffected households, approximately 1-4% of persons reported diarrhoea lasting longer than three days in the previous month, and 2% of persons reported diarrhoea on the day of the survey. Households in affected areas reported a higher rate of diarrhoea of any duration compared with households in unaffected areas, but not for likely parasite infections lasting three days or more (Table 5).

Discussion

The second household survey did not detect any increase in disease likely to be attributable to drinking Sydney water. The increased reporting of diarrhoea lasting three days or more in households in affected areas is not consistent with illness due to waterborne parasites, and most likely represents reporting bias.

Table 5
Household survey 2. Characteristics and responses of persons in Sydney, The Blue Mountains, The Hunter, and Illawarra areas 4 - 8 September 1998 (preliminary analysis)

A survey was conducted by the Sydney Morning Herald (SMH) on 15-16 September and published in the SMH on 19 September prior to lifting of the second boil water alert. Data from the survey indicated that a higher proportion of people reported drinking unboiled tap water than found in NSW Health surveys 14% continued to drink unboiled tap water and a further 19% drank unboiled tap water at some time. While the results of the surveys by SMH and NSW Health are not directly comparable due to differences in timing, sampling and questions asked, the SMH survey indicates a possible underestimation by the first two NSW Health surveys of people who continued to drink unboiled tap water in areas affected by alerts.

Household survey number 3 Third Event
Background

During the time Sydney water was possibly contaminated with oocysts of *Cryptosporidium* and cysts of *Giardia*, testing at several points in the water distribution system showed that the water from pipes in certain streets in north west Sydney contained the organisms, suggesting that residents in these streets were more likely to have been exposed. NSW Health conducted a third telephone survey focussing on the residents of those streets.

Streets where the organisms were found and the number of each type of organism found in the water are displayed in Table 6.

Table 6. Results of examination of reticulated drinking water samples taken from selected streets in northwest Sydney on 4 & 7 September 1998

Telephone interview method

The telephone numbers listed in the electronic white pages (Australia on disc, May 1998) of residences in the streets listed in Table 6 were identified. Residents who answered telephone calls during the period 23 and 24 September were interviewed. The boil water alert had been lifted on 19 September.

A questionnaire similar to that used for the second Sydney water survey was used in this survey of selected residences in north west Sydney.

Results

Table 7 lists the findings of the survey.

Table 7. Results of the telephone survey of selected residences in north west Sydney, 23 & 24 September 1998

Summary

Among all respondents, 11% reported diarrhoea during the six weeks before interview (only six reported an onset of diarrhoea after 11 September). None reported diarrhoea on the date of interview.

Among the 24 respondents who drank unboiled water during the week 5-11 September, 10% reported diarrhoea in the six weeks before interview (only one reported onset of diarrhoea after 11 September) and none reported current diarrhoea.

The results for this survey are similar to the results of the previous two surveys.

Conclusions

Data from the enhanced surveillance do not suggest any increase in diarrhoeal illness in the Sydney area during and following the contamination incidents. Surveillance mechanisms used have been shown capable of detecting increases in disease associated with swimming pools.

The small non-significant increase in *Giardia*sis is likely to be attributable to increased testing and identification of background cases unrelated to drinking Sydney water.

Similarly, the household surveys did not detect any increase in disease likely to be attributable to drinking Sydney water.

Availability of medication generally used to treat *Giardia*sis and diarrhoea

Following the public alert to boil Sydney tap water before consumption, media reports have suggested that stocks of the drug Fasigyn (used to treat *Giardia*sis) were in short supply.

On 10 September 1998, public health units in Sydney were asked to contact selected chemists in their areas to determine whether they had noted increased sales of the antibiotics to treat *Giardia*sis (Fasigyn or Flagyl), and whether they were aware of the reasons that these drugs have been prescribed.

Most chemists surveyed reported increased sales of Fasigyn and Flagyl since the public alert. Chemists in Wentworth, south western Sydney, central Sydney and northern Sydney areas reported that they had sold out of Fasigyn since the public alert. The two chemists surveyed in south eastern Sydney had not noted an increase in sales.

Many chemists reported that it was their understanding that doctors were prescribing Fasigyn or Flagyl because persons with diarrhoea were assumed to have *Giardia*sis, and were treated accordingly.

In light of the lack of evidence of waterborne illness following the public alert, it is likely that the increased sales in drugs to treat *Giardia*sis may represent a wider use of these drugs in persons with diarrhoea not shown to be caused by *Giardia*sis.

Conclusions

Many chemists reported increased sales of the antibiotics used to treat *Giardia*sis since the first boil water alert was announced. However, these findings are inconclusive, as it is likely that increased sales represent a wider use of these drugs in persons with diarrhoea not shown to be caused by *Giardia*sis.

Surveillance of immuno-compromised population

The National Centre for HIV Epidemiology has increased its surveillance for evidence of increased diagnoses of cryptosporidiosis in persons with HIV in Sydney. No increase has been noted.

Additional epidemiological data

Solicitors Slater and Gordon have advised the Inquiry that they have been contacted by approximately 450 individuals about gastrointestinal illnesses which they consider to be related to the recent contamination of Sydney's water supply. Slater and Gordon advised the Inquiry that they had interviewed and obtained instructions from 65 of those individuals. Of the 65 people interviewed, 15 had been diagnosed with *Giardia*sis on the basis of pathology test results. Another 35 were diagnosed with *Giardia*sis on the basis of reported clinical symptoms alone.

It is not possible to tell from the information provided to the Inquiry whether the 15 diagnosed cases of *Giardia*sis were caused by waterborne transmission. The number of cases is not inconsistent with normal background levels of incidence of the disease (between 600 and 800 cases identified by pathology tests per year in NSW over the last few years).

Conclusions

Taking into account:

1) the levels of *Cryptosporidium* and *Giardia* found in Sydney drinking water during the contamination episodes;

2) the fact that those levels were significantly higher than those that have caused disease outbreaks overseas; and

3) survey findings indicating that a significant percentage of the population consumed unboiled water during these periods, an increase in gastroenteritis caused by *Cryptosporidium* or *Giardia* would have been expected.

However, considering the comprehensive data summarised above, I conclude that it is unlikely that there was any increase in infection with *Cryptosporidium* or *Giardia* during any of the events. On the basis of current scientific knowledge, it is not possible to determine whether this was due to the strain, the viability of the organisms or some other reason. The lack of infectivity of the organisms has been confirmed by studies in the USA, although these are not definitive.

The results from laboratory tests in the United Kingdom showed that many of the parasites isolated during the First Event appeared degraded, and their species could not be determined. It therefore seems probable that the parasites present in the First Event were unlikely to cause infection. This hypothesis is supported by the absence of an outbreak of disease at the time of the First Event. Similarly, few of the raw water samples from the Second Event tested positive by the FISH test, indicating that the *Cryptosporidium* may have been degraded and non-infectious.

There is dispute about test results showing the existence of *Cryptosporidium* and *Giardia* in finished water during the Third Event. There is little agreement between the results from the different laboratories. Accordingly, I am unable to determine whether the lack of illness in the community was due to an absence of parasites, or the fact that the parasites were not infectious to humans.

An additional factor which may explain the lack of disease is the level of protective immunity of the general Sydney population, due to pre-exposure.

The Inquiry has commissioned serology studies to clarify the role of protective immunity in the recent contamination of Sydney's water. Unfortunately, the results of the studies will be unavailable before the Inquiry is completed. I recommend that NSW Health be made responsible for publishing the results of all of the studies once they are available.

While there was no apparent illness as a result of the recent contamination incidents, I believe that the boil water alerts were appropriate in the circumstances. Considering the significant health risk to at least part of the population, a conservative public health approach is warranted.

Solicitors Slater and Gordon have made a submission challenging my conclusions about the apparent lack of any increase in diarrhoeal illness in Sydney associated with the events. Slater and Gordon have commenced a representative action on behalf of persons who claim to have become ill as a result of consuming water supplied by Sydney Water between July and September 1998.

Slater and Gordon claim that a substantial increase in the absolute numbers of *Cryptosporidium* and *Giardia* infections may have occurred but may not have been detected by the surveillance strategies. They argue that there were a number of limitations to the surveillance strategies, including the size of the household survey samples, the inability of the strategies to identify non-symptomatic illness (the individual is not aware he or she is infected) and the use of criteria that only considered diarrhoea lasting for more than three days as likely to be due to *Cryptosporidium* or *Giardia*. Slater and Gordon also dispute my finding that the small increase in *Giardia*sis reported in August was not significant.

I have carefully considered Slater and Gordon's arguments, but do not consider the conclusions I have previously expressed should be modified. While it is true that no epidemiological study can exclude very small changes in the incidence of diarrhoea, the fact that several different strategies failed to find any evidence of an increase in disease suggests that if there was an increase it must have been very small (less than 1-2% in proportionate terms which is no more than background variation). Previous experience shows that the surveillance mechanisms used by NSW Health are capable of identifying outbreaks of cryptosporidiosis following swimming pool contamination. There is no reason to believe the same techniques would not have identified illness in the wider population.

With regard to the reported increase in *Giardia*sis, I am satisfied that it was very small in percentage terms. When considered with the results of the other surveillance, I believe the increase was more likely explained by extraneous factors, in particular the increased testing for *Giardia*sis as a result of the publicity given to the contamination of the water supply.

What is international best practice on boil water alerts?

United States Centers for Disease Control and Prevention

The United States Centers for Disease Control and Prevention (CDC) states that "finding low levels of *Cryptosporidium* oocysts in finished water should not be the reason for issuing a boil water alert notice for the general public, unless the decision is supported by other data that suggested that water quality is not acceptable"(CDC, 1995).

Accordingly, the CDC Guidelines for Issuing or Rescinding a Boil Water Advisory When *Cryptosporidium* or Other Waterborne Pathogens are Suspected do not set specific pathogen levels or any other parameters that would trigger a boil water alert. They state that such specificity has been omitted because:

- the health risk associated with the consumption of drinking water contaminated with small numbers of *Cryptosporidium* oocysts is unknown;
- for *Cryptosporidium* and other emerging pathogens (mostly viruses, also Cyclospora and the Microsporidia), analytical methods for detection in water samples are developmental and may lack the sensitivity and specificity that would permit decisions to be made on the need for boil water alerts based on results alone. Negative results do not necessarily indicate the absence of organisms. Positive results do not provide an accurate assessment of the number of organisms present nor of their infectivity or viability. Hence a numerical standard for the number of organisms that would be of concern has not been developed;
- the level of concern for some parameters can be site-specific; and
- the complex interplay of factors to consider in making boil water alert decisions makes it difficult to set national criteria that could be used by all communities.

Instead, the guidelines recommend that local taskforces (including water treatment professionals and physicians) be established to assess public health responses to contamination incidents case by case. The guidelines propose a number of sets of factors to consider at various points in the decision-making process. These include:

- circumstances or events that warrant a meeting of the taskforce to review data that would be relevant to a boil water alert;
- factors the taskforce should consider in evaluating whether a boil water alert is necessary; and
- factors the taskforce should consider in making a decision to rescind the boil water alert.

Factors to be considered in evaluating whether a boil water alert should be imposed or rescinded include:

- source water quality indicators (including pathogen levels, faecal coliforms, Escherichia coli and turbidity) and the vulnerability of the source to contamination;
- treatment effectiveness and distribution system integrity;
- finished water quality indicators (including pathogen levels, faecal coliforms, Escherichia coli and turbidity); and
- epidemiological evidence, that is evidence that associates gastrointestinal illness in the population with drinking water.

Milwaukee USA response protocol

The largest documented outbreak of cryptosporidiosis caused by contamination of a public water supply occurred in Milwaukee, Wisconsin during March and April 1993. A boil water alert was issued to 880,000 customers serviced by the Milwaukee Water Works when the Health Department became aware of widespread community illness through phone calls from citizens and media reports. The decision to issue a boil water alert was based on the following factors:

- widespread gastrointestinal illness;
- a review of complaints of taste and colour of water from one of the treatment plants in late March;
- a significant increase in turbidity of finished water during that time; and
- laboratory confirmation of *Cryptosporidium* in the stool specimens of eight ill persons.

The level of oocysts found in ice frozen during the contamination incident showed maximum concentrations of between 26 and 53 oocysts per 100 litres and mean concentrations of between 12 and 23 oocysts per 100 litres. Ranges are due to varying estimates of the loss of oocysts caused by thawing ice sampled (Craun et al, 1998). MacKenzie et al (1995) believe that the concentration of *Cryptosporidium* oocysts found in the tested ice vastly underestimates the peak level in water from the southern plant due to losses during the freeze-thaw process and insensitivity of testing procedures.

In addition to the issue of a boil water alert, the treatment plant, suspected at the time to be causing or contributing to the contamination, was temporarily shut down.

An intensive surveillance program which followed determined that over 400,000 became ill after exposure to *Cryptosporidium* in the drinking water. *Cryptosporidium* infection was confirmed in more than 700 people with gastrointestinal illness in association with the outbreak. A study of death certificates in the Milwaukee vicinity following the outbreak showed that 54 *Cryptosporidium* associated deaths, concentrated in the immuno-compromised population, occurred during the two year post-outbreak period compared with four in the two years before the outbreak (Hoxie et al, 1997).

Although the cause of the contamination was never definitively established, it was thought to be due to a combination of failure of effective filtration, and contamination from either sewage, agricultural waste or slaughterhouse effluent. There has not been a recurrence of waterborne disease in Milwaukee.

Following the outbreak, a response protocol was introduced to apply if *Cryptosporidium* or *Giardia* was found again in treated water in Milwaukee. The protocol involves the establishment of a Water/Health Technical Group which meets regularly and, following any positive test results, reviews available water quality, technical and epidemiological data.

The protocol is based on the CDC advice that low levels of *Cryptosporidium* or *Giardia* in treated water should not trigger a boil water alert unless supported by other data suggesting the water quality is unacceptable. The Technical Group is responsible for assessing the potential implications of a positive sample in relation to other data or events. Other data to be considered include weather; source water quality; raw, backwash and filter effluent turbidities and particle counts; and relevant epidemiological data.

The Technical Group is responsible for advising the Mayor, who in turn is responsible for deciding on the appropriate health response which may include:

- consultation with relevant authorities;
- institution of daily monitoring;
- issue of a boil water alert; and
- shutdown of a water treatment plant.

After the outbreak, guidelines were also developed for immuno-compromised individuals, recommending that they consult with their physician on an ongoing basis about drinking water and health risk.

Las Vegas USA

During the first quarter of 1994, 78 laboratory confirmed cases of cryptosporidiosis were reported in people living in Clark County, Nevada. Of the 78 cases, 63 were HIV infected persons and at least 20 died from cryptosporidiosis. The cases were widely distributed throughout the county and the treated water supply was thought to be the cause of the infection. People who drank unboiled water were four times more likely to become infected that those who did not. Those who were severely immunosuppressed and drank unboiled tap water were 13 times more likely to become infected (Goldstein et al, 1996).

Water for the county came from Lake Mead and was filtered and disinfected before entering the distribution system. During the outbreak, there were no reports of elevated turbidity or coliform bacteria and no *Cryptosporidium* oocysts were detected in raw or treated water serving the county. However, *Cryptosporidium* samples were only collected monthly and it was thought that this sampling program failed to detect sporadic entry of the parasite into the distribution system. There were also no apparent deficiencies or breakdowns in the treatment or distribution systems.

There is still some argument whether this outbreak was waterborne, although the widespread geographic distribution and broad range in ages of affected persons are consistent with waterborne transmission.

The lack of positive test results for *Cryptosporidium* during the incident illustrates why test results should not be used as the only indicator of whether a waterborne outbreak of cryptosporidiosis has taken place.

Following the outbreak, the Clark County health authorities issued a health advisory recommending that AIDS patients take independent action to protect themselves from *Cryptosporidium* by boiling their water for at least one minute.

United Kingdom

In the United Kingdom drinking water guidelines for *Cryptosporidium* and *Giardia* are based on the Badenoch Experts Group Reports on *Cryptosporidium* in Water Supplies, 1990 and 1995. A third report of the Experts Group, chaired by Professor Ian Bouchier, was released in November 1998. The third report supports the Badenoch approach and makes further recommendations for best practice on the basis of more recent experience and scientific findings.

The Badenoch Report (1995) states that "currently there is no way of defining an acceptable threshold level of oocysts and decisions on action must be based on local experience and agreement between water utilities, health authorities and local authorities" (page 26). The Bouchier Report (1998) recommends that water utilities, in liaison with health authorities, set and periodically review criteria for decision-making on the issue and withdrawal of boil water alerts.

The decision to impose a boil water alert in England and Wales is made by established Incident Control Teams comprising water industry and public health professionals. While some water utilities specify trigger levels for consideration of a boil water alert, the presence of *Cryptosporidium* oocysts in the water is not alone considered sufficient reason to impose a boil water alert. Considerable reliance is placed on the collective professionalism and experience of the Incident Control Team.

In Scotland, ultimate authority for public health response to a water contamination problem lies with the local authority. Except in the rare instance when a high level contamination incident has occurred, measurement on one parameter alone is considered insufficient to develop an opinion on the risk. Each detection must be assessed for public health significance in the context of previous trends or results and operational history of the supply.

The response options when there is possible contamination of drinking water by pathogens, demonstrated by 'indicator' organisms, include substitution of water supply from another works, increasing disinfection or issue of a boil water alert. (Indicator organisms, such as faecal coliforms, are used to indicate the possible presence of pathogens which occur in faeces). The most appropriate response is determined on the basis of knowledge of the supply, treatment process, the cause of the incident and the assessment of risk to public health. The assessment of public health risk is made by the local Consultant in Public Health Medicine. Use of an alternative water supply or the issue of a boil water advice are considered appropriate options when the health consultant considers the concentration of the pathogens present pose a significant risk to public health.

To try and resolve difficulties facing water and health authorities in determining whether a health risk associated with water is present, significant medical risk values for water parameters have been published by the Environmental Health Unit including, for instance, coliforms and E. coli, but not *Cryptosporidium* and *Giardia*. However, it is emphasised that the values indicate the level at which dialogue among interested health professionals must commence. They are not action levels for initiating boil water alerts or cessation of use of supply.

In relation to the immuno-compromised, the 1990 Badenoch report recommended that the Department of Health should draw doctors' attention to the need to advise patients on ways to minimise the risk of contracting infection from *Cryptosporidium*, including water and food consumption, hygiene and sexual practices. This recommendation is the basis of current practice in the UK. The 1995 Badenoch report took a stronger position recommending that people with advanced cases of impaired immunity should avoid drinking unboiled water.

Significantly, the Bouchier report (1998) has recommended that, as a precautionary measure, immuno-compromised persons should be advised to boil all tap and bottled water used for drinking.

Studies on appropriate public health response

Studies of outbreaks of waterborne cryptosporidiosis and *Giardia*sis and clinical feeding trials have resulted in some recommendations for action levels relating to the concentrations of cysts and oocysts found.

Action levels

Haas and Rose (1997) have proposed an action level of 10 to 30 *Cryptosporidium* oocysts per 100 litres in drinking water, suggesting that an outbreak is possible when oocyst concentrations are within and above this level. The level is based on oocyst concentrations detected during a number of waterborne outbreaks in the United States of America and United Kingdom. Action is defined to include:

- examining watershed changes and treatment modifications;
- considering additional sampling with expedited processing; and
- considering a communication program with physicians treating the immuno-compromised, nursing homes and other at risk groups.

However the authors concur with the Centers for Disease Control advice that a positive result alone should not trigger a public health alert.

Craun et al (1998) evaluated the action level proposed by Haas and Rose on the basis of an analysis of 12 reported cryptosporidiosis outbreaks, including the one in Milwaukee. They found that in four of these outbreaks, no oocysts were detected. In the remaining eight outbreaks, at least one sample that was collected during each outbreak detected fewer than 10 oocysts per 100 litres. The authors point out that if information available from this single sample was used on its own, the proposed action level would not have been exceeded in any of the reported outbreaks. This confirms the general agreement that deciding action on the basis of one sample is not advisable. If action levels were based on the mean concentrations of oocysts detected in all samples collected during each outbreak (or the maximum levels when there is insufficient data to calculate a mean), only half of the water systems that reported an outbreak would have exceeded the action level proposed by Haas and Rose (including Milwaukee).

Wallis et al (1996) propose a lower action level for *Giardia* of three to five cysts per 100 litres in treated drinking water on the basis of data from outbreaks. Wallis et al also emphasise that while a single sample containing *Giardia* cysts above the action level is cause for immediate concern, repeat sampling is necessary to establish a trend and as many as 10 samples may be required to describe the range of cyst concentrations that a community is experiencing in its water supply.

What is international best practice on public information reporting?

US Safe Drinking Water Act public information requirements

The United States Safe Drinking Water Act contains detailed public notification requirements in respect of violations of the National Primary Drinking Water Quality Regulation. A two-tiered notification system is established prescribing timeframes, frequencies, contents and types of notices to be issued to the public, depending on the severity of the violation.

A Tier 1 notification is required when the system fails to comply with a maximum contaminant level or a prescribed treatment technique, or does not comply with allowed variations or exemptions. These events require a notice to appear in a local newspaper or to be delivered by hand, at least once within 14 days of the violation. If a Tier 1 violation poses an acute risk to human health, notice via electronic media (radio and TV) is required within 72 hours.

A Tier 2 notification is required when a system fails to comply with monitoring requirements or a testing procedure prescribed by a National Drinking Water Regulation, or when it operates under a

variance or exemption. These events require a notice in a local newspaper, or to be delivered by hand, within three months.

In addition, the United States Safe Drinking Water Act Amendments will require water suppliers to deliver consumer confidence reports at least once a year to each customer. The reports will:

- tell consumers where their water comes from and whether it meets federal drinking water standards;
- identify potential sources of any contaminants found and potential health effects if standards are violated;
- include special health advisories for immuno-compromised persons; and
- tell consumers where to get more information on water quality.

What steps have been taken to ensure an effective public health response in the event of future contamination incidents in Sydney?

NHMRC developments

Following my First Report, the NSW Government requested the National Health and Medical Research Council (NHMRC) to conduct an accelerated revision of the provisions of its 1996 guidelines, focusing on *Cryptosporidium* and *Giardia*.

Currently, the NHMRC guidelines do not recommend an acceptable level for the organisms or routine monitoring. The guidelines recognise that monitoring for specific protozoan pathogens is complex, expensive, time-consuming and may fail to detect their presence in water. When the diseases cryptosporidiosis or *Giardia*sis are detected in the community through clinical or epidemiological studies, the guidelines recommend that action to control the organisms may be necessary, based on suitable advice from the local health authorities on the necessary action to protect public health.

A new draft guideline is expected to be released for public comment shortly. It is understood that the issues the guideline will address include appropriate monitoring regimes and possible public health responses to positive findings of *Cryptosporidium* and *Giardia*. However, it is expected that the NHMRC will not specify either acceptable standards for *Cryptosporidium* and *Giardia* in drinking water or action trigger levels.

I note that the NHMRC process involves public consultation in addition to consultation with national and international experts, and this is wholly appropriate. The guideline is expected to be endorsed by the NHMRC in July 1999 and will provide a useful basis for review of NSW guidelines and protocols at that time.

The NSW Health Interim Protocol

NSW Health issued an Interim Response Protocol Following Detection of *Giardia*l Cysts or Cryptosporidial Oocysts in Drinking Water in September 1998, which appears below. The protocol includes responsibilities and criteria to consider in deciding on public health action, including the issue of boil water alerts. The protocol makes it clear that the Chief Health Officer is responsible for the issue of boil water alerts and outlines the role of the Expert Panel in advising the Chief Health Officer.

The Government has since amended the Public Health Act to give the Chief Health Officer the exclusive statutory responsibility for issuing boil water alerts, as part of a package of new regulatory powers for NSW Health. I support the amendments.

THE PROTOCOL
NSW Health Department
19 September 1998

Access to safe drinking water is an important factor in maintaining good public health.

Over recent times, variable levels of the parasites *Cryptosporidium* and *Giardia* have been found in the Sydney drinking water system. High levels combined with a number of other factors have led to advice to the community to boil drinking water as a public health precaution. This has been the case both in Sydney between July and September this year and in a number of overseas countries at various times.

There are a series of barriers to prevent contamination in our drinking water. The first of these is catchment and storage protection; the second, a water treatment process such as chlorination and filtration and lastly, safe operation of the distribution system.

Public health authorities have an important role in monitoring the quality of our drinking water to determine the potential for public health risk. This role includes assessment of a number of factors including results of water sampling; illness levels in the community and the effectiveness of filtration. Following assessment, public health authorities put in place whatever measures may be necessary to minimise health risk to the community.

Why an interim response protocol?

When the first 'boil water' advice was issued in July 1998, NSW Health immediately introduced a number of key measures. These included:

- the establishment of an Expert Panel of microbiologists and parasitologists;
- an expanded surveillance program to identify any increased illness in the community; and
- an enhanced water testing regime.

The Chief Health Officer, in collaboration with the Expert Panel, developed a response protocol for contamination in Sydney's drinking water. This protocol was intended to provide guidance for the convening of the Panel, assessment of water samples and other results and the issuing or lifting of 'boil water' advice or any other public health measure. The approval system for the protocol has involved a strict and independent two-step process.

Approval from the Expert Panel was the first step. The second occurred when NSW Health submitted its protocol to the Sydney Water Inquiry, an independent inquiry headed by Mr Peter McClellan QC and commissioned by the NSW Government. Mr McClellan QC, in his second interim report, called for the development of a refined interim protocol by NSW Health with advice from the Expert Panel.

The need for an interim protocol stems from the fact that scientific knowledge in the area of infection from contamination of drinking water is not conclusive. Much scientific debate surrounds both the potential health risks to the community from the presence of parasites such as *Cryptosporidium* and *Giardia* in drinking water and the effectiveness of water filtration systems in removing these parasites. The relationship between levels of these parasites in drinking water and water borne illness is not clear.

However the Sydney water experience is leading to a substantial increase in international scientific knowledge on drinking water quality.

NSW Health together with the Expert Panel has now refined the response protocol which can be used until more is known about the source or cause of the current situation. This interim protocol has been reviewed by experts from around Australia including members of the National Health and Medical Research Council (NHMRC).

Are people getting sick?

The primary aim of NSW Health is to protect public health. The best scientific evidence indicates that there has been no increase in reported illness that is attributable to the water supply.

Since the first 'boil water' advice, NSW Health has twice surveyed around 430 households with a further survey planned for next week. In addition, all laboratories have been asked to notify positive results of *Cryptosporidium* and *Giardia*. NSW Health has also been making regular contact with pharmacies, GPs and emergency departments to complete the picture.

These processes additionally inform NSW Health in determining whether to issue or lift boil water advice.

Although there is also no evidence of increased cryptosporidial illness among persons with HIV, a more cautious approach is usually taken for those with weakened immune systems. It is likely that health professionals will continue to advise people with compromised immune systems to boil their water.

It has been common practice for some clinicians to advise their immuno-suppressed patients to boil water as a matter of routine. People in this group include people living with HIV-AIDS and transplant patients. It has also been a long standing practice that parents are advised that water should be boiled if used for drinking by infants under one. Some people suffering from cancer may also be immune-compromised. Anyone who is concerned should seek advice from their GP.

NSW Health endorses these practices.

What happens next?

Drinking water quality will remain a priority area for NSW Health.

The expanded surveillance system will continue to monitor the health of the community through surveys; notifications of disease; GP consultations; medication use and Emergency Departments.

Some diarrhoeal illness occurs all the time in our community. NSW Health will fund a targeted study to look at why people contract diarrhoeal illness and whether the cause is water borne contamination. Expressions of interest will be called shortly for scientists with the qualifications to undertake a research project of this size and complexity.

Studies commissioned by other States and overseas will be examined closely and will provide NSW Health with the most up to date information.

At the Government's request, the National Health and Medical Research Council is, as a matter of urgency, reviewing the 1996 Australian Drinking Water Guidelines relating to *Cryptosporidium* and *Giardia*. The new guidelines are expected to be released for consultation in December, 1998 with final ratification by July, 1999.

These processes will further inform NSW Health protocols.

Mr Peter McClellan QC, has commissioned a number of studies to assist in clarifying the scientific issues surrounding drinking water quality. These studies include:

- using overseas laboratories to verify the type of *Cryptosporidium* and its potential viability and health impacts;
- a series of tests to help understand how filtration plants remove varying proportions of *Cryptosporidium* and *Giardia*; and
- a complete review of the water distribution system.

Interim Response Protocol
Following Detection of *Giardia*l Cysts Or Cryptosporidial Oocysts in Drinking Water

1. NSW Chief Health Officer Responsibility

The NSW Chief Health Officer has the responsibility for issuing advice to the public regarding measures available to minimise risk from disease, including water-borne disease.
In relation to drinking water, this responsibility requires the Chief Health Officer to rapidly assess any report of:

- breakdown in the water treatment system;
- contamination of the water supply; or
- clusters of illness potentially due to the former.

and ensure action is promptly taken to address the problem including where appropriate issuing a boiled water alert.

2. Investigation of Positive Findings in Treated Water

Where testing of treated water for *Giardia*l cysts or cryptosporidial oocysts has been performed, the detection of parasites at any level will trigger an investigation by the water agency for potential failures of water treatment (see 3 below). The water agency will inform NSW Health of positive *Giardia*l or cryptosporidial results within one hour.

2.1 The investigation triggered by a positive finding should include (but not be limited to) an assessment of:

a) the accuracy of the findings (ie, confirmation that parasites are present);
b) viability of the organisms;
c) chlorination;
d) flocculation and filtration;
e) presence of faecal coliforms, total coliforms and total heterotrophic bacterial counts;
f) pre-treatment contamination of the raw water;
g) post-treatment contamination of the water (eg. local ingress of material) and
h) turbidity in raw and treated water and particle counts where available.
Immediate re-sampling of the affected part of the system, adjacent areas of the system and areas downstream from the affected area of treated water, will be carried out.

2.2 The water agency will move to correct any deficiencies and keep NSW Health advised where:

a) chlorine levels are found to be inadequate, or
b) coliforms are detected in treated water or total bacterial counts are elevated, or
c) flocculation or filtration systems are found to be failing, or
d) a recent contamination of the raw water is identified, or
e) a contamination of treated water is detected.
The Chief Health Officer will consider the need for a boiled water alert, and other public health response or the convening of the Expert Panel, where:
a) any of the criteria listed in 2.2 above exists; and
b) there is detection of Cryptosporidia or *Giardia*.

3 Role of the Expert Panel

The Expert Panel which has assisted the Chief Health Officer to date will have a permanent ongoing role as a Standing Committee. The advice of the Expert Panel will be valuable to assist the Chief Health Officer in making a decision on the most appropriate health response.
The Chief Health Officer will seek advice from the Expert Panel in situations including the following:
a) where deficiencies specified in 2.2 above are identified and it is still possible that persons will consume inadequately treated water (as advised by Sydney Water) but the health consequences are unclear and/or

b) where the results of re-sampling (as specified in 2.1 above) confirm the presence of parasites at levels calculated to be greater than 10 *Giardia*l cyst or 100 cryptosporidial oocysts in 100 litres of treated water, but no deficiencies are identified and
c) as otherwise required.
If an outbreak of illness occurs in the population due to infection with *Giardia* or Cryptosporidia, the Health Department will investigate and manage the incident following its standard procedures. If the Chief Health Officer has reason to suspect that the cause of the outbreak may be related to the consumption of drinking water, s/he may seek advice from the Expert Panel.

4 Public Health Action

In deciding on the issuing of a boiled water alert, the Chief Health Officer will consider:

- detected levels of contamination;
- viability of organisms versus effectiveness of disinfection;
- time and scale of exposure including the likely recency of the contamination;
- evidence of increased illness in the present or previous events;
- the likelihood of effective identification and rectification of any water system problem;
- the need to communicate accurate and appropriate information to the community in a timely and effective way;
- the community impact of any public health action; and
- the advice of the Expert Panel.

Protection of public health is a dominant element. The Chief Health Officer must also consider the possible adverse consequences of a boiled water alert for example - scalds.
The potential responses available to the Chief Health Officer include:

- no further public health response required and continued surveillance for illness;
- issuing of public reminders of precautionary measures for immunocompromised individuals and possibly other groups with higher risk of secondary infection (nursing homes, preschools, daycare centres).
- boiled water alert;
- public alert for need for increased hygiene measures.

The option chosen would clearly depend on the assessed level of public health risk and the potential benefits to the community or specific groups within the community from that response. For example, where results of a routine test are positive but subsequent tests are clear, and continued exposure to contaminants is unlikely, then there is no clear public health benefit from calling a boiled water alert. However, it maybe useful to increase surveillance for illness and to continue to monitor the situation closely.

5 Lifting the Boil Water Alert

The NSW Chief Health Officer has the responsibility for lifting boiled water alerts. The Chief Health Officer will take into account the following factors:

- detected levels of contamination;
- viability of organisms versus effectiveness of disinfection;
- duration and scale of exposure of the population to contaminated water;
- evidence of increased illness in the present or previous events;
- the likelihood of effective rectification of any water system problem;
- the predicted clearance or flow time of clear water through the water distribution system;
- the need for additional testing;
- the need to communicate to the public which areas have been released from the boil water alert in a timely and effective way; and
- the adverse impact to the community, which may be associated with delaying lifting.

Conclusions on the Interim Protocol

The interim protocol is broadly in line with international best practice. In particular, there is general agreement that a range of factors need to be considered in determining the appropriate public health

response and deciding on the use of an expert panel. These include the presence of *Cryptosporidium* and *Giardia* in source and treated water, treatment effectiveness and epidemiological evidence.

I believe that the interim protocol produced by NSW Health was appropriate at the time to ensure an agreed basis for decision-making in the event of further contamination events. However, further scientific and technical information has come to light in the course of the Inquiry which raises doubts about the usefulness of some criteria included in the protocol. These are:

- viability of the organisms as one of the criteria to be considered in the decision to issue or rescind a boil water alert; and

- prescribed levels of *Cryptosporidium* and *Giardia* (10 *Giardia*l cysts or 100 cryptosporidial oocysts in 100 litres of water) which require the Chief Health Officer to seek advice from the expert panel.

Viability

While viability is an important indicator of the infectivity of organisms and therefore of the health risk they pose, it is now apparent that current viability testing is unreliable. There is considerable work under way on developing testing methodologies with some promising results. However, it may be some time before a reliable test agreed by the experts is found. Given the status of the methodology, viability should not be included as one of the criteria to be considered in determining appropriate health action at this stage. The risk of including viability in the criteria is that unreliable test results indicating non-viability may be used to argue against an appropriate health response.

Levels of *Cryptosporidium* and *Giardia*

There is an ongoing debate about the levels of *Cryptosporidium* and *Giardia* which constitute a threat to public health. Although high levels of *Cryptosporidium* and *Giardia* in water may not result in illness, studies have suggested that one organism alone may cause infection in a vulnerable person. International literature shows a lack of agreement on appropriate action or trigger levels for public health responses. International best practice appears to generally avoid the specification of a particular level of *Cryptosporidium* or *Giardia* as a trigger for the issue of a boil water alert.

In view of this uncertainty and the possibility that one organism alone may cause infection, I am concerned about including any trigger levels in the protocol. My concern is that specification of a level may provide a rationale for not responding to a potentially significant public health incident. The Chief Health Officer's decision to issue a boil water alert should be based on a range of factors including the presence of *Cryptosporidium* and *Giardia* at any level. Given that the Chief Health Officer now has statutory responsibility for issuing boil water alerts, the decision to seek the advice of the expert panel should be at the Chief Health Officer's discretion. This may well be made when the presence of *Cryptosporidium* and *Giardia* are at levels significantly lower than those currently specified. In effect this is a more stringent standard. The mere presence of *Cryptosporidium* or *Giardia* should trigger action by NSW Health, although it may not involve issuing a general boil water alert.

Accordingly, I believe the protocol needs to be amended to remove reference to viability and specific levels of *Cryptosporidium* and *Giardia*. I have discussed this with NSW Health and they are reviewing the protocol. My discussions with NSW Health lead me to believe that the revised protocol will be appropriate.

The NSW Health Response Protocol should be an evolving document and regularly reviewed in response to the results of further epidemiological studies, developments in scientific knowledge, and international best practice. My recommendations on future research priorities are contained in Chapter 16.

The protocol should also be reviewed on finalisation of the NHMRC guidelines.

What further steps are needed to ensure an effective public health response?

Special measures for the immuno-compromised

The interim protocol does not include reference to infants or immuno-compromised people.

NSW Health has indicated that the current advice to families recommends that children under one year be given boiled water only. I believe that this advice is generally followed throughout the community. However, it should be reinforced through available mechanisms.

However, recommended health protection measures for immuno-compromised groups are much less clear. Current NSW Health advice to these groups is:

"Evidence to date does not suggest that drinking Sydney water will place anyone at risk for cryptosporidial illness. However, the following groups of people, after consultation with their doctor, may wish to avoid unboiled drinking water:

- people living with HIV and AIDS
- people receiving treatment for some types of cancer
- transplant patients."

(Drinking Water and Public Health, NSW Health, Sept. 1998).

I do not believe this advice is appropriately worded. I have received a number of submissions complaining that the advice is confused. The announcements which accompanied the lifting of the boil water alert in September have also been criticised. The message must be made plain.

NSW Health should issue a further advice to the immuno-compromised community in New South Wales, making clear the potential risks from *Cryptosporidium* in water and from other sources. The advice should state that all tap water that might be consumed by immuno-compromised persons should be brought to the boil and allowed to cool before use. This advice is consistent with international best practice. Appropriate quality control also needs to be introduced for bottled water and home filter systems.

Because of the continuing scientific uncertainty about the relationship between *Cryptosporidium* and *Giardia* in the water supply and illness and the potentially fatal effects of *Cryptosporidium* on immuno-compromised persons, I believe a conservative response must be taken.

The issuing of the permanent notice should be accompanied by an education campaign targeting the immuno-compromised community and those providing health advice and services to this community. The campaign is discussed below in the section on public education. Guidelines on the implementation of the notice should be issued by NSW Health to medical practitioners, hospitals, and other health facilities providing services to the immuno-compromised.

How can the general public be better informed about *Cryptosporidium* and *Giardia*?
Publication of test results

During the recent contamination events, Sydney Water initiated the publication of all treated water sample test results on its Internet Web site. NSW Health took responsibility for reporting any positive results directly to the public via the electronic media.

There is now a legitimate expectation that results of tests for *Cryptosporidium* and *Giardia* will continue to be made public. In my view the public must be informed of future instances of contamination and any risks to the drinking water supply. All information about water quality should be published.

Sydney Water's practice of posting all test results on its Web site should continue and NSW Health should continue to publicise any results with potential public health implications.

Reports on drinking water quality

To help restore public confidence in the drinking water supply, regular reports should be provided on the quality of the Sydney's water. The reports should cover a range of health indicators including *Cryptosporidium* and *Giardia*.

In my Third Interim Report I recommended that the catchment authority report regularly to Parliament on the state of the catchment and the achievement of water quality objectives. Legislation has since been passed by the Parliament which gives Sydney Water and the Sydney Catchment Authority significant public reporting responsibilities in relation to water quality.

The Sydney Water Catchment Management Bill 1998 provides for the establishment of a Sydney Catchment Authority and the preparation of two yearly audits on the state of the catchment for presentation to Parliament.

In addition, the Water Legislation Amendment (Drinking Water and Corporate Structure) Act 1998 requires Sydney Water to produce and publish three monthly consumer confidence reports on the quality of drinking water. Summaries of the reports and details of their availability are to be provided to each customer with their account. The reports are to include:

- details of the quality and quantity of water in the Corporation's catchment areas;
- an evaluation of the effectiveness of the Corporation's treatment of water from its catchment areas during the preceding three months;
- a review of developments in the literature concerning drinking water quality issues faced by water suppliers worldwide; and
- an overview of catchment management issues of significance during the preceding three months.

In addition to these measures, the Chief Health Officer has decided to publish an annual report on drinking water quality which informs the public of the state of the drinking water supply from a health perspective. Inclusion of a range of health indicators, not only *Cryptosporidium* and *Giardia*, would be appropriate.

I support these measures to ensure that public is fully informed about drinking water quality issues and trends.

Public education

While transparency of test results and water quality indicators is critical, information provided to the public must also be meaningful. Publication of hundreds of test results without context or explanation may not be helpful.

A public health education campaign should be developed to provide the community with an informed understanding of the health risks associated with *Cryptosporidium* and *Giardia*, possible sources of infection and recommended precautions.

Some of the messages which need to be included in the campaign are:

- *Cryptosporidium* and *Giardia* are commonly found in the environment and humans are exposed to these organisms in the course of their everyday activities;
- there are more common methods of transmission of *Cryptosporidium* and *Giardia* than drinking water;
- a number of processes remove or reduce the level of microorganisms in drinking water, such as catchment management, treatment and disinfection. However, these processes cannot remove all organisms, and drinking water is not sterile;

- the presence of *Cryptosporidium* and *Giardia* may not involve a health risk it depends upon a range of variables including the source, the species or strain, the viability of the organisms, the infectivity and the immunity of the individual;
- there are limits in the present scientific technique used for testing for *Cryptosporidium* and *Giardia*. It is difficult to determine whether they are alive or dead and whether the potentially infective C. parvum species is present;
- infections caused by *Cryptosporidium* and *Giardia* are usually mild in the general population; and
- cryptosporidiosis in the immuno-compromised community may be severe and result in premature death.

Clear advice should be provided on recommended precautions for all types of transmission, including boil water advice when an alert is in place. Conflicting public health information on the appropriate time necessary to boil water (one or three minutes) was issued during the first boil water alert in Sydney. Bouchier (1998) has since recommended that water should be brought to the boil only and then allowed to cool before consumption. This has been shown to be adequate and lessens the risks of scalding.

The general public education campaign should be accompanied by a special campaign targeting the immuno-compromised community to convey clear and consistent messages to at risk groups about the permanent boil water alert. The public campaign should be accompanied by an information and education program for medical practitioners, focusing on advice they should give to the immuno-compromised, and providing detailed state-of-the-art scientific information on the risks posed by *Cryptosporidium* and *Giardia*.

The content and design of the education campaigns are critical. They must be carefully formulated, the message must be understood by all members of the public and they must be based on the latest available expertise. The campaign targeting the immuno-compromised should be developed in consultation with peak bodies representing the immuno-compromised community.

To ensure the public education campaigns are designed to reflect expert opinion and best practice, I recommend the establishment of a Ministerial advisory committee to advise the Minister for Health on public information issues associated with *Cryptosporidium* and *Giardia*, with a focus on public education. The role of the committee could be expanded over time to include consideration of public information and education issues relating to other drinking water quality parameters.

Chapter 10: The regulatory framework

How was the regulatory framework developed for the Corporation?

Before corporatisation

Until 1995, the Water Board was a statutory authority, established under its own Act and directly controlled by a Minister in its day-to-day operations. Both the Managing Director and the members of the appointed Board were selected by the Minister and subject to direction. The role of the Board was ambiguous. Ultimately, the only independent function of the Board was its ability to express its opinion about decision making in a report to the Minister. Board members were not accountable under the Corporations Law.

Why was Sydney Water corporatised?

By the mid 1990s a number of factors were influencing the Government to reform the constitution of the Water Board. Three fundamental urban water industry microeconomic reforms were being contemplated:

- separation of the roles of regulator and operator;

- introducing market prices for operators' services based on user-pays principles; and

- establishment of a commercial framework for operations through corporatisation.

Deficiencies in the way the organisation was constituted were becoming obvious. There was the lack of clarity about the Board's role and the main purpose of the organisation. The structure of the Water Board was perceived to inhibit performance, to act as a barrier to competition and to lead to conflicts of interest. The transparency of financial arrangements was under question.

The reform agenda was also influenced by the National Competition Policy. This questioned whether the best outcomes for the community were achieved by the institutional structure and broader framework within which Government utilities such as the Water Board operated. Under the National Competition Policy, there was increasing pressure for bodies such as the Board to generate returns equivalent to those earned by commercial bodies. These principles gained support through the Council of Australian Government's agenda and had the support of all States and Territories.

Economic imperatives underpinned the urban water microeconomic reform activities in all jurisdictions. Reforms focused on the introduction of market-based pricing and greater cost recovery. A primary objective was to ensure that water services to consumers provided an appropriate return to Government and did not impose an inappropriate financial burden on Government budgets.

A key report in early 1995 was the Urban Water Research Association of Australia's report entitled Urban Water, Markets and the Hilmer Reform Process. It found that whether water operations were private or public agencies had little effect on improvements in efficiency and outcomes. It identified little real benefit in franchising the operation of various components of a water, sewerage or stormwater drainage system. The report's preferred model for institutional reform within the urban water industry was to corporatise the relevant authorities. It also recommended including in water prices the costs imposed by, but external to, the industry, such as the cost of environmental damage from water supply works.

The report stressed that the core difficulty in reform lies with the natural monopoly elements of the water industry. Its view was that traditional Government-owned water agencies need to be split between operator and regulator functions. The most efficient operational outcomes would be achieved through competitive inputs to the markets. Inputs, both capital and labour, would ideally be outsourced to the greatest extent possible.

The Water Board had already made changes to reflect these directions. Competition was increasing significantly in the Board's operations and there was an increased focus on productivity gains, reducing costs, pricing reform and charging real economic prices for goods and services. Some contestable services, such as maintenance and electrical services, had already been contracted out.

Another argument in favour of corporatisation was that it would provide a clearer regulatory framework and accountability for the Water Board. It would be clear that the Government and regulatory agencies had the public policy role of determining the outcomes that the community as a whole wants from its water and sewerage systems, such as setting ecological, water quality and health standards. The operational agencies would have the clear responsibility of undertaking their day-to-day operations in the best way to achieve these outcomes.

Once corporatised, the organisation would meet regulatory requirements laid down by the Environment Protection Authority, NSW Health and other regulators. It would also obey tax and corporation laws. If required to meet social obligations, community service obligations would be made explicit and reimbursed by the Government.

Another, somewhat subordinate, objective of the microeconomic reform agenda for urban water agencies was achieving improved environmental outcomes. User pays pricing was presented as a means of reducing the demand for water. Indeed, it was noted at the time that pricing reforms introduced by the Hunter Water Corporation had reduced water consumption by 30%. As well as lessening the need for agencies to undertake costly augmentation, it was argued that user pays pricing would conserve total water use and free up a proportion of the supply for environmental purposes.

The separation of the operator and regulator roles, inherent in corporatisation, was also presented as having environmental benefits. As an operational organisation, "Sydney Water would no longer assume all responsibility for environmental management, regulation, planning" (Paul Broad, Managing Director, August 1993). After corporatisation, the Board would not abdicate its duty of environmental care but would simply meet the tests met by other corporate and private citizens, such as being required to comply with all environmental and planning legislation. It would remove the conflicting situation of the Board determining its own developments, such as water filtration plants.

In summary, the objectives of the urban water industry microeconomic reforms in general, and of corporatisation in particular, were identified as follows:

- to provide focus on core business and customer service;
- to be more open with and accountable to the community;
- to remove barriers to better performance;
- to clearly divide operator and regulator responsibilities;
- to provide environmental and health benefits;
- to improve commercial performance; and
- to allow for increased competition.

How did corporatisation proceed?

The legislation enabling corporatisation, the Water Board (Corporatisation) Bill 1994 (WBC Bill), was introduced into Parliament by the Hon Robert Webster, Minister for Planning and Housing on 22 September 1994. As the Government was a minority Government, the Bill's passage depended on the support of the non-aligned Independent Members of Parliament.

There was significant interest in the legislation from peak environmental and consumer interest groups which viewed corporatisation as an opportunity to impact upon the operations of a major agency involved in polluting activities. They were also intent on ensuring that broader environmental, consumer and health considerations did not receive less attention than commercial ones.

The groups lobbied for a different model of corporatisation to that set up by the framework legislation for corporatisation of Government businesses in NSW, which was the State Owned Corporations Act 1989 (SOC Act). The Act requires state owned corporations (SOCs) to have the principal objective of being a successful business. It also strictly limits Ministerial intervention in the affairs of company SOCs. The Hunter Water Board had been corporatised under this Act in 1991, as a company SOC.

With the support of the Independents, the Government's draft Bill was rejected and the interest groups were able to negotiate a range of amendments with the Minister and Managing Director. Both the Government and the Board supported the amendments in the interest of pursuing the broader microeconomic reform of utilities recommended as part of the National Competition Policy.

New aspects of corporatisation

The WBC Bill applied the SOC Act to the Water Board, creating the new Sydney Water Corporation. The amendments negotiated between the Government, interest groups and the Independent MPs imposed a number of additional requirements on Sydney Water.

First, the Bill established explicit environmental and public health objectives that had equal standing with the Corporation's commercial objectives.

Second, it established a number of additional regulatory mechanisms to control the operations of Sydney Water. These mechanisms, discussed later in this chapter, include an Operating Licence, a Licence Regulator and Memoranda of Understanding between Sydney Water and its primary regulators.

In addition, the financial and other accountability mechanisms contained in the SOC Act, the WBC Bill and Operating Licence ensured that the Corporation continued to be subject to a number of additional public sector accountability mechanisms, including Freedom of Information legislation, the Ombudsman, the Independent Commission Against Corruption and the Government Pricing Tribunal.

Third, the Bill created a new model of corporate structure. The Minister responsible for the Operating Licence became answerable to Parliament. This was a major change from the situation under the SOC Act. It followed concerns raised by the Labor Opposition and the Independents that the Westminster doctrine of Ministerial accountability to Parliament had been unacceptably weakened by the Act. The Bill also provided for the Parliament to disallow proposed amendments to the Operating Licence that authorised the Corporation to operate.

At the time there was concern in the Parliament that the Government's intention was to privatise the Board at a later date. A Saulwick Poll in November 1994 recorded that 75% of the NSW community supported Government ownership of water supplies. The Parliament agreed to amendments that explicitly placed barriers in the way of privatisation. Effectively, a public inquiry into the potential social, environmental and economic impacts of any proposal was required before it could be pursued.

Fourth, the WBC Bill provided specific mechanisms for environmental accountability, including provisions for the protection of the integrity of water catchments, pollution reduction targets and enforcement rights for third parties on environmental protection and customer service matters.

The regulatory environment

When the legislation was before Parliament, there was a perception by the environment groups and the Labor Opposition that the regulatory framework surrounding the proposed corporatised body was inadequate.

"If corporatisation proceeds there will be considerable gaps in the regulatory and operating framework ... It would be dangerous to simply corporatise the board, placing upon it a stronger financial and commercial imperative than currently exist, without its regulators being equally as well equipped to protect the public interest." (Ms Allan MP, Hansard, 27 October 1994)

The Labor Opposition had supported corporatisation in principle, but expressed concerns about the adequacy of the environmental protection regime. The Opposition unsuccessfully attempted to delay the corporatisation of the Board until there was integrated and revised environmental protection legislation.

"Unless there is a strong, clear whole of Government approach to the regulatory framework that governs Government trading enterprises, the international experience makes it clear that ultimately the operators will dominate. They set the standards, they set the prices, and they ultimately become the tail that wags the dog." (Mr Knowles MP, Hansard 2 December)

However, while the Independent Members of Parliament and the environmental groups were critical of the Government for not having reformed pollution laws, they did not support delay of the corporatisation, subject to certain conditions. These included the establishment of a new statutory authority, the Licence Regulator, to monitor the Corporation's compliance with its Operating Licence and to give advice to the Minister responsible for the Corporation.

While the Licence Regulator could advise the Minister on penalties or remedial action over the Corporation's performance, its role was perceived by some to be more a public watchdog rather than a regulator.

"This little pearl could be more properly entitled the regulator you have when you don't have a regulator, to make up for a pretty inefficient EPA." (Mr Knowles MP, Hansard, 2 December)

The Australian Conservation Foundation representative, Tony Simpson, however described it "a very teethy watchdog".

Sydney Water was also required to enter into statutory based Memoranda of Understanding (MoU) with NSW Health, the Environment Protection Authority and the Water Administration Ministerial Corporation (custodian of the state's water resource), described as a:

"new era in memoranda of understanding. The MoUs will ensure cooperative relationships between those regulating agencies and Sydney Water aimed at guaranteeing the sharing of information and joint studies..." (Mr Souris MP, Hansard, 2 December)

As a result of the parliamentary settlement, there emerged a series of complex questions about objectives, priorities, performance and accountability. The attainment of the three equal objectives relating to commercial, environmental and public health matters would require trade-offs at various levels within the Corporation.

Environmental outcomes that might otherwise have been imposed on the Corporation by an external regulator were written into the way the Corporation was to undertake its business. These were objectives and special provisions to reduce risks to human health and prevent the degradation of the environment as well as the adoption of pollution reduction targets. This marked a major deviation from the classic model of corporatisation.

Concerns about the ability of the regulatory framework to support this novel corporatisation process were arguably prophetic. The external regulators, with the possible exception of the EPA, were largely unprepared to deal with the consequences of "standard" corporatisation and had little perception how to deal with corporatisation as enacted. There was no body to oversight or coordinate within Government the new regulatory environment in which this unusual "creature" would operate.

What it meant for the protection of the catchments

There were concerns expressed in the Parliament about the future management of catchment lands and the Corporation's commitment to catchment protection.

Provisions were introduced into the WBC Bill and Operating Licence to safeguard the catchment lands that drain to Sydney's water storages such as Warragamba, Illawarra and Shoalhaven areas and to manage the lands to preserve water quality and ecological integrity. These areas were required to be managed in accordance with Joint Plans of Management to be entered into by the Corporation with the National Parks and Wildlife Service.

In addition to the Corporation's right to comment on proposed activities and developments in the vicinity of the storages, a limited referral role was enshrined for the outer reaches of the catchments extending to the urban centres of Lithgow to the north, Goulburn to the west and Braidwood in the south.

Catchment land could not be sold or otherwise disposed of by Sydney Water except to the National Parks and Wildlife Service or as permitted by legislation. Guidelines were to be issued by Sydney Water requiring councils to consider the cumulative impact of development on water quality when approving additional development in the catchment.

A comprehensive planning instrument for the water supply catchment areas was to be developed to ensure an integrated and consistent approach to decisions about land use and development.

Corporatisation legislation is passed

The WBC Bill was passed by the Lower House on 2 December 1994 with the support of the non-aligned Independents and the environment groups.

Dr Macdonald MP described the Bill as a landmark piece of legislation (Hansard, 2 December 1994).

Minister Webster, MLC said:

"I was delighted to be in the Legislative Assembly on Friday evening when the Bill passed through that chamber and to receive the warm congratulations of the environment movement... The Government amendments had the support of all non-aligned Independents in the other place."
(5 December)

Mr Jeff Angel of the Total Environment Centre said:

"This is a quality product which has the potential to deliver a better environment for Sydney and its aquatic environment. The Government and the Independents have been creative and far sighted in sponsoring the long running negotiations that have led to this new Bill."

The Act was fully commenced by 1 January 1995.

What is the current regulatory framework?

For Sydney Water

The Water Board (Corporatisation) Act 1994 (WBC Act) provides for the establishment of the Corporation and its objectives and provides the ongoing powers necessary for operations.

Under the Act, Sydney Water has three principal objectives: to be a successful business; to protect the environment; and to protect public health by supplying safe drinking water to its customers. These objectives are of equal standing.

The WBC Act requires the establishment of key elements of the regulatory framework for Sydney Water including:

- Operating Licence a regulatory mechanism on monopoly power setting out operating and customer standards to be met by the Corporation, including a Customer Contract;
- Licence Regulator a new body to monitor compliance with the conditions of the Operating Licence; and
- Memoranda of Understanding to spell out Sydney Water's relationships with its primary regulators, namely the Environment Protection Authority, NSW Health and the Water Administration Ministerial Corporation.

The WBC Act applies the SOC Act to the Corporation, which in turn provides the framework for Sydney Water's corporate structure, its shareholder relations and the establishment of a Board.

Sydney Water was established under the SOC Act as a company state-owned corporation. The voting shareholder Ministers are the Treasurer, currently the Hon Michael Egan MLC, and one other eligible Minister nominated by the Premier, currently the Hon Paul Whelan, MP. There are currently three non-voting shareholder Ministers, the Hon Carl Scully, MP; the Hon Faye Lo Po', MP; and the Hon Gabrielle Harrison, MP. The Corporation is under the control and direction of a Board of Directors of seven people appointed by the voting shareholders and the Managing Director of Sydney Water.

The WBC Act provides for the separation of responsibilities of the shareholding Ministers, the operating licence Minister and the regulatory Ministers.

The operating licence Minister is currently the Hon Craig Knowles MP, Minister for Urban Affairs and Planning. As such, he is responsible for administering the provisions of the WBC Act relating to Sydney Water's Operating Licence and reporting to Parliament on Sydney Water's operations.

The regulatory Ministers are: the Hon Dr Andrew Refshauge, MP, Minister for Health; the Hon Pam Allan, MP, Minister for the Environment; and the Hon Richard Amery, MP, Minister for Land and Water Conservation.

For the Sydney Catchment Authority

In response to the recommendations of my Second and Third Reports, the Government introduced legislation to establish the Sydney Catchment Authority (SCA), to carry responsibility for management of Sydney's drinking water catchments and bulk water supply.

The Authority will manage and protect the Inner and Outer Catchment areas and associated infrastructure, supply bulk water (to Sydney Water and any other water supply authorities), and regulate certain activities within or affecting the catchment areas. Importantly, the Authority will be responsible for ensuring the catchment areas are managed to optimise water quality and will ensure water supplied by the Authority complies with appropriate standards of quality.

The Authority will assume Sydney Water's responsibilities, including ownership of land, in the inner catchment. The Sydney Water Catchment Management Bill 1998 (SWCM Bill) provides for the Authority to exercise a concurrence power over development in both the Inner and Outer Catchments. It provides for concurrence and other roles in the granting of licences under other legislation, such as the pollution control legislation, which affects the catchment areas. The Authority will also be able to exercise an inspection or enforcement role under other legislation in relation to activities carried out in the catchment area.

The legislation makes the Authority subject to a similar regulatory framework to Sydney Water involving an Operating Licence, auditing by the Licence Regulator and requirements to enter into Memoranda of Understanding with the Environment Protection Authority, NSW Health and Water Administration Ministerial Corporation. Some variations in application of the framework are discussed.

What are the problems with the regulatory framework?

The Operating Licence

The WBC Act gives the Governor the power to grant an Operating Licence to enable Sydney Water to provide systems or services in its area of operations.

The Operating Licence defines the terms and conditions under which the Corporation will operate and establishes mechanisms for customer participation. It sets out operating and customer standards, including water quality standards, however these do not cover *Cryptosporidium* or Giardia.

The Operating Licence includes a Customer Contract which spells out the rights and responsibilities of both customers and of Sydney Water. The Contract details rights to the supply of water, sewerage and drainage services, consultation, information and assistance, notice of interruption to supply and customer redress when Sydney Water does not meet its obligations. This may include a rebate on the service availability charge.

The WBC Act provides that the initial term of the Operating Licence would be for a maximum of five years after which it could be renewed. The Operating Licence is required to be reviewed mid-term and independently audited on an annual basis or as directed by the Minister. The audit findings are required to be tabled in the Parliament.

In my view, the Operating Licence does not constitute an effective regulatory mechanism. There is insufficient accountability in the processes required for developing the terms of the initial licence and any amendments. Sydney Water essentially wrote its own licence, although admittedly it undertook considerable consultation on its terms. There is no requirement in the WBC legislation for public consultation on the development of the initial licence, although the initial licence was required to be tabled in Parliament with the legislation and was subject to amendment by Parliament. Similarly, public consultation is not required before introducing any amendments to the licence or a new Operating Licence, although both are subject to disallowance by Parliament.

The SWCM Bill requires the SCA's Operating Licence and any amendments to be tabled within 90 days of the granting of the licence or amendment, but does not provide for disallowance.

Both the WBC Act and SWCM Bill provide for cancellation of the Operating Licence in a number of circumstances, for instance when Sydney Water or the SCA cease to carry out any of their responsibilities. However, this is a purely hypothetical penalty in view of the essential nature of water supply services and the lack of an alternative provider. It does not constitute a meaningful sanction.

The Operating Licence is clearly out of date with respect to the nominated drinking water quality standards. It requires drinking water to meet the 1980 NHMRC guidelines immediately and the 1987 guidelines according to an agreed timetable negotiated with NSW Health. Sydney Water has since agreed with NSW Health to endeavour to meet the 1996 NHMRC guidelines. Furthermore, reliance of the Operating Licence on the NHMRC guidelines means that it contains no requirements for *Cryptosporidium*. The NHMRC guidelines do not currently require routine monitoring of *Cryptosporidium* and Giardia, nor do they specify acceptable levels of the two organisms. I believe the community now expects some reference to *Cryptosporidium* and *Giardia* in both Sydney Water's and the SCA's Operating Licences. In the longer term, specific requirements for water filtration plants should be included in the Operating Licence as discussed in Chapter 11.

The mid-term review of the Operating Licence in November 1997 found a number of deficiencies. The review was conducted by a working party of Sydney Water and Licence Regulator representatives, chaired by the Department of Urban Affairs and Planning. Recommended changes included adding new or amended clauses to give customers clear guarantees of standards of service and to provide cost effective service to consumers, to take into account changes in regulatory arrangements affecting Sydney Water's operating environment, and to remove redundant clauses.

Conclusions

I believe the current Operating Licence should be replaced by a new licence which clearly outlines for both Sydney Water and the Sydney Catchment Authority:

- the authorities' obligations in terms of customer and operating/health outcomes the focus of Sydney Water's Licence would be on customer service and public health obligations, while the SCA Licence would have a stronger focus on environmental obligations;
- actions to be taken and sanctions to be applied in the event that obligations are not met; and
- audit and review provisions clearly outlining the role of the Licence Regulator and the processes, timeframes and other triggers for review, including the introduction of revised standards and future contamination events.

It is critical that the licence is developed through a consultative and transparent process which is at arm's length from Sydney Water and the Sydney Catchment Authority. There should be opportunities to review operating standards in line with changing community expectations and an increased understanding of costs and benefits.

I understand that the Government intends to establish the Sydney Catchment Authority by 1 July 1999 and note that the Authority has bipartisan support. It will therefore be necessary to develop the Operating Licence for the Authority in the first half of next year. Sydney Water's Operating Licence is due for renewal on 1 January 2000.

Given that the establishment of the Authority will entail significant changes to Sydney Water's responsibilities and consequently its Operating Licence, I believe the development of the SCA's licence and the review of Sydney Water's licence should be conducted concurrently, as part of an independent and public consultative process.

I believe that the Independent Pricing and Regulatory Tribunal (IPART) is an appropriate body to conduct this initial consultation process and achieve the necessary balancing of public health, environmental and commercial objectives required in development of the licence terms. IPART should be requested to make recommendations to Government on the terms of the SCA's initial licence and Sydney Water's next licence to apply from 1 July 1999. Its recommendations should be developed through a transparent and highly consultative process involving expert advisers, Government bodies

and the general public. Subsequent reviews should involve the restructured Licence Regulator, as discussed.

The Licence Regulator

The Licence Regulator is a statutory body corporate consisting of five part-time members appointed by the Minister. Membership includes representation from environmental, consumer, water industry and business interests, in addition to a nominee of the Minister administering the Water Administration Act 1986.

Despite its title, the Licence Regulator is essentially an auditor. It is responsible for monitoring and reporting to the Minister on compliance with Sydney Water's Operating Licence conditions. Its primary task is the commissioning of an independent annual audit of the Corporation against the Operating Licence requirements and reporting on the Corporation's performance to the Minister.

The Minister is required to table the audit in Parliament and decide on any actions resulting from the independent audit and advice from the Licence Regulator. The Licence Regulator is not subject to the direction or control of the Minister for the contents of any report, including the annual audit.

In my Third Report I recommended that the Licence Regulator be restructured and provided with the necessary powers and resources to become an independent auditor for Sydney's catchment. This would involve auditing the activities of the Sydney Catchment Authority and the activities of the primary regulators in the catchment.

The Government's Bill to establish the Sydney Catchment Authority (SCA) makes the Authority subject to the Licence Regulator. The Bill extends the Licence Regulator's existing powers to the SCA. It also empowers the Regulator to monitor and report on compliance of other authorities (such as the EPA and the Department of Land and Water Conservation) with the provisions of the regional environmental plans.

The Bill includes a provision for the Minister to make regulations conferring other functions on the Licence Regulator. Minister Knowles said in his second reading speech that this was in anticipation of any further recommendations I might make about the role and functions of the Licence Regulator.

Conclusions

I believe the Licence Regulator should remain responsible for auditing Sydney Water's operations within its newly defined area of responsibilities. However, as I mentioned in my last report, presently there are obstacles to the Licence Regulator performing an effective critical review of Sydney Water's operations. These come from constraints on the Licence Regulator's powers and resources. Unless these problems are addressed, they will also restrict the Licence Regulator's ability to effectively audit the SCA and other public authorities operating in the catchment.

The Licence Regulator's role and structure needs to be modified to enable it to undertake a stronger and better-defined role in the management of Sydney's water. It should be renamed so that its title more effectively communicates its enhanced role perhaps the "Water Auditor".

I believe that the Water Auditor should be able to investigate and audit any matter concerning the performance of both authorities against their Operating Licences annually. The Water Auditor should also be able to conduct random spot audits in relation to any matter with the agreement of the Minister. I understand that there has been dispute between Sydney Water and the Licence Regulator about the scope of the Licence Regulator's audit powers and whether it is empowered to audit all aspects of the Operating Licence.

The Water Auditor must be clearly empowered to audit the operations of parts of Sydney Water and the Sydney Catchment Authority which are owned and/or operated by organisations external to the authorities, but form part of the overall treatment and distribution system. This includes the water filtration plants. This may require an adjustment to the contract.

I believe that the Water Auditor should have a role in the development and review of the terms of the Operating Licences. As the restructure of the Licence Regulator will require new legislation which should be introduced in the Autumn session, it is unlikely that the new Water Auditor would be in a position to oversight the review of Sydney Water's licence and development of the first SCA licence, to apply from 1 July 1999. For this reason, I have recommended that IPART conduct the process described above. However, I believe the Water Auditor should be involved in subsequent reviews.

The structure and resourcing of the Water Auditor should reflect its roles and responsibilities. It should comprise a full time Executive Director and appropriate full time staff. The Water Auditor's Board should remain small and comprise the Executive Director together with the non-executive chair and directors who have a proven track record in balancing the interests of all stakeholders as well as experience in appropriate areas such as health, environment, consumer affairs, business, finance, water and engineering.

The independence of the Water Auditor is critical. It should have the power to report to Parliament. The Government should review its relationship with the shareholding, Operating Licence and regulatory Ministers to ensure that conflicts of interest are removed.

Powers of the Operating Licence Minister

The powers of the Minister responsible for Sydney Water's Operating Licence under its establishing legislation are limited. The Minister's powers of direction are limited to the power to direct actions to rectify any contravention of the Operating Licence and to direct Sydney Water to perform non-commercial activities. His powers to request information are limited to information which demonstrates Sydney Water's compliance with its Operating Licence.

As I concluded in my Second Report, the recent contamination incidents clearly demonstrated the need for the Operating Licence Minister to have sufficient power to obtain information from the Corporation and, if circumstances require, give a direction to the Corporation which is in the public interest.

The Water Legislation Amendment (Drinking Water and Corporate Structure) Act 1998 gives effect to my conclusion by changing Sydney Water Corporation and Hunter Water Corporation from company to state-owned corporations under the SOC Act. This provides the portfolio Minister with the power to obtain information relating to the affairs of Sydney Water and Hunter Water and to give directions to the Boards of the Corporations on matters of public interest.

A further amendment to Sydney and Hunter Water's enabling legislation will give the Minister greater powers to direct the Corporations than currently provided for under the SOC Act, by removing the current requirement for the portfolio Minister to consult with the Board before issuing a direction. The portfolio Minister will be empowered to give a direction to Sydney Water and Hunter Water that is in the public interest after consultation with the Treasurer, but without first consulting the Board if that is warranted on the grounds of urgency, public health or safety.

To avoid the accountability problems experienced in relation to Sydney Water, the SWCM Bill proposes that the SCA be subject to the control and direction of the Minister, except in relation to the contents of any report or recommendation made by the Authority.

I support the amendments to Sydney Water's corporate structure as an effective way of increasing the ability of the portfolio Minister to direct Sydney Water. I also support the Ministerial accountability requirements in the SWCM Bill.

The Memoranda of Understanding

The WBC Act requires Sydney Water to enter into a separate Memorandum of Understanding (MoU) with each of its regulators, that is the Environment Protection Authority, NSW Health and the Water Administration Ministerial Corporation. The Act requires the MoUs to be exhibited to the public and comments considered before finalisation.

The Operating Licence defines the general purpose of the MoUs, which is to clarify roles and responsibilities and facilitate cooperative relationships between the signatories.

MoU with NSW Health

The MoU with NSW Health recognises the Department's role in regulating drinking water quality and imposes obligations on Sydney Water in relation to provision of safe drinking water. It also outlines procedures to facilitate effective interaction between the two parties.

The MoU requires Sydney Water to meet the health related parameters of the 1996 NHMRC guidelines from 1 July 1997 and to investigate customer complaints about water quality. In addition, the MoU imposes obligations on Sydney Water for the monitoring and reporting of drinking water quality, provision of data to Health and notification of water system events indicating a potential health hazard, with parallel responsibilities assigned to NSW Health. A water quality monitoring plan, prepared according to the terms of the MoU, requires Sydney Water to regularly monitor and report to NSW Health on *Cryptosporidium* and *Giardia* levels.

MoU with Water Administration Ministerial Corporation

The Water Administration Ministerial Corporation, which is in practice the Department of Land and Water Conservation, regulates Sydney Water's access to water. The MoU defines the rights and accountabilities of both parties in relation to water access, use and management. Specifically, it confirms Sydney Water's right, provided in the WBC Act, to exercise within its area of operations the right to use, the flow and control of water vested in the Ministerial Corporation.

The MoU includes a joint undertaking by both parties to influence water and land use activities to minimise adverse effects on the quality of water entering the water resources used by Sydney Water. It also includes principles and processes for cooperation and provisions for joint studies and data exchange.

The MoU states that the memorandum is a more formal definition of rights and accountabilities and is intended to form the basis of the Water Use Licence to be issued by the Ministerial Corporation.

MoU with Environment Protection Authority

The MoU recognises the EPA as the environmental regulator of the State and commits Sydney Water to environmental improvements and to monitor and report on the environmental performance of its activities while the EPA is required to audit the results.

The EPA is responsible for ensuring Sydney Water meets the environmental objectives and obligations outlined in the WBC Act and Sydney Water's Operating Licence. These obligations include meeting any EPA licence conditions or other requirements in the operation of its water distribution, sewerage or stormwater systems, meeting of pollution reduction targets set by the EPA, and environmental reporting.

The MoU requires the EPA to verify information provided by Sydney Water to the Licence Regulator on matters related to EPA's interaction with and regulation of Sydney Water.

Sydney Catchment Authority MoUs

Legislation establishing the SCA imposes a similar requirement to enter into MoUs with the primary regulators. In addition, the Bill provides for the Minister to direct the Authority to enter into an MoU with other agencies including the National Parks and Wildlife Service, NSW Agriculture, local councils, county councils or other nominated agencies.

Conclusions

It is my view that the Memoranda of Understanding between Sydney Water and its regulators are not effective as regulatory mechanisms, particularly when unsupported by clear powers in the regulatory agency's own legislation. The MoUs are unenforceable, relying on the cooperation of the agencies involved for effective implementation.

While the EPA has clear powers in its legislation to regulate Sydney Water activities which involve a discharge to the environment and the Water Administration Ministerial Corporation has clear rights to regulate the use of water, NSW Health perceived itself to have limited statutory powers to support its role in the MoU during the contamination events.

The WBC Act provides little guidance about the content of the MoUs. There is no requirement for the MoUs to include targets, timeframes or review provisions. A strong emphasis is placed on the development of cooperative relationships between the agencies, rather than clearly defining the regulatory contracts.

There is also no body clearly accountable for the content of MoUs. The Licence Regulator has responsibility for verifying that the MoUs are in existence and the terms are being honoured but its role does not extend to consideration of the content or adequacy of the MoUs. The Licence Regulator has argued that its ability to effectively review the performance of Sydney Water is limited by the lack of targets and timelines in the MoU, making it difficult to quantify progress.

The Operating Licence should be amended to require that MoUs include targets, timelines and review provisions, and specifically require the Licence Regulator to audit their content. The existing MoUs between Sydney Water and its regulators should be reviewed against these new requirements urgently.

The same scrutiny should extend to the proposed MoUs between the Sydney Catchment Authority and its regulators and other agencies.

Health regulatory powers

The Public Health Act 1991 provides a range of emergency powers for the Minister for Health in relation to public health risks, including unfit drinking water. The Act also establishes a surveillance system that requires laboratories and practitioners to notify NSW Health when cases of specified diseases are identified. These included cryptosporidiosis at the time of the incident. Giardiasis has recently been added to the list of specified diseases. The surveillance system assists the Department in monitoring the incidence of these diseases and developing appropriate public health responses.

At the time of the contamination events there was no detailed regulatory regime in the Public Health Act for drinking water. NSW Health's powers to regulate drinking water were limited to:

- emergency powers under the Public Health Act to respond to public health threats posed by water supplies, in particular the power vested in the Minister for Health to restrict or prevent the use of drinking water which the Minister has reason to suspect is unfit; and
- the requirement in the WBC Act that NSW Health enter into an MoU with Sydney Water which recognises NSW Health's role in drinking water quality standards. This commits Sydney Water to supplying water which is safe to drink, having regard to the health of the public.

The MoU is inadequate and not a substitute for an effective regulatory instrument.

My Second Report reviewed the management of the contamination incident and recommended that NSW Health's powers to regulate water quality should be strengthened. In response, the Government introduced amendments to the Public Health Act to strengthen NSW Health's regulatory powers in relation to drinking water.

The Water Legislation Amendment (Drinking Water and Corporate Structure) Act 1998 empowers the Director-General of NSW Health to: authorise entry of premises of any supplier of drinking water to carry out inspections and take samples of water; direct a drinking water supplier to provide

information; and require a water supplier to carry out tests on water. Severe penalties are proposed for breaching these provisions, and for failure of any water supplier to inform the public on the safety of drinking water. The amendments also allow for the development of regulations on quality assurance programs for suppliers of drinking water.

The legislation provides for the Director-General to declare that the Chief Health Officer has the exclusive function of deciding whether to issue a boil water alert in relation to any supplier of drinking water.

The legislation is an effective means of clarifying and strengthening NSW Health's powers in relation to drinking water quality.

The complaints mechanism

The Customer Contract spells out the rights of Sydney Water customers and outlines its policies and procedures for handling complaints and giving redress, such as a rebate on service availability charges and compensation if services are not provided at agreed standards.

Sydney Water has an internal customer complaints handling mechanism which involves contacting the 24 Hour Emergency Service Centre or local Sydney Water Office. The final decision in resolving any complaint rests with the Sydney Water Regional Manager.

If a customer is not satisfied with the internal complaint process, the Customer Contract suggests that the customer may pursue the matter through an external body such as the Ombudsman's Office or the Consumer Claims Tribunal. Other external options might include a Community Justice Centre or the Conflict Resolution Network.

The Licence Regulator has responsibility for reviewing Sydney Water's response to customer complaints, according to the terms of the Operating Licence and Customer Contract. However, the Licence Regulator has no formal power to investigate or resolve actual complaints and is confined to reporting back to Sydney Water and to the Operating Licence Minister. The Licence Regulator has received 200 complaints over the past three years of which 120 were found to be substantive, with one third resolved in the customer's favour after being referred back to Sydney Water.

The Department of Fair Trading has submitted to me that there is a need for a permanent alternative dispute resolution (ADR) mechanism for ongoing complaints which are not resolved by Sydney Water's internal mechanism. Approximately 300,000 complaints are made to Sydney Water each year. This figure includes reports of service interruption or requests for information which may be resolved at first contact, in addition to complaints involving disputes. Experience in other utilities suggests that 1-5% of disputed complaints are not resolved at company level. The NSW Ombudsman's Annual Report 1996-97 showed that only 21 complaints were referred to the Ombudsman that year.

The Independent Pricing and Regulatory Tribunal (IPART) has also suggested that an independent complaints mechanism is needed to handle general complaints and claims on incidents such as the recent contamination events. The Tribunal has recommended that the Government consider creating a public utility ombudsman, funded by the utilities, to deal with customer complaints involving electricity, gas and water.

Many industries have an ADR scheme, for example the Banking Industry Ombudsman, Financial Planning Complaints Resolution Scheme, Energy Industry Ombudsman, and Telecommunications Ombudsman. In some industries licence conditions require companies to belong to an ADR scheme which meets specified minimum standards. Examples include telecommunications and NSW electricity industries.

The Energy Industry Ombudsman's role is to respond to customer complaints about the electricity industry on issues such as billing, connection and disconnection, security deposits and actions by electricity suppliers which affect customers' properties. The emphasis of the scheme is on conciliation

and resolution of complaints by providing information and mediation, but if complaints cannot be resolved the Ombudsman can make a determination up to $20,000 or $50,000 with the agreement of the parties.

The Energy Industry Ombudsman is funded by electricity providers in NSW. The office currently employs three full-time investigation officers in addition to several clerical staff. The Ombudsman works with a Council made up of representatives of consumer, small business and industry interests.

Conclusions

There is a need to ensure that Sydney Water's internal complaints mechanism is as effective as possible and to establish a permanent alternative dispute resolution (ADR) mechanism for ongoing complaints which are not resolved by Sydney Water's internal mechanism.

I note that there is an Australian Standard on Complaints Handling, and believe that Sydney Water should be required to ensure that its internal complaints mechanism meets that standard. In addition, the Water Auditor should retain a role in auditing Sydney Water's complaints processes.

The Government should consider the establishment of an external dispute resolution mechanism to deal with complaints which are unable to be resolved by the internal process.

Options worthy of consideration include:

- requiring Sydney Water to join the existing Energy Ombudsman scheme, broadening it to a Utilities Ombudsman. This would avoid a proliferation of schemes and spread the cost of the energy scheme more widely. It would require agreement of the Energy Industry Ombudsman Council; or
- requiring Sydney Water to set up a water industry ADR scheme. A NSW scheme should be quick to establish, as there are many precedents.

Any additional requirements in relation to complaints mechanisms should be incorporated in Sydney Water's Operating Licence.

The Government should also consider how the chosen mechanism might apply to other water suppliers in New South Wales.

Chapter 11: Water quality standards

Introduction

The need for public confidence

The most significant challenge for Sydney Water is to restore public confidence in the quality of Sydney's drinking water. Measures have been introduced by the Government to improve the quality of the catchment. The contamination events have, however, initiated public debate about the need for water quality standards or other performance measures.

Consumers presently rely on assurances that Sydney Water is abiding by its Operating Licence, voluntary national guidelines, the Memorandum of Understanding with NSW Health and NSW Health's interim protocol. These documents do not contain any standards for *Cryptosporidium* and Giardia.

The setting of acceptable levels for *Cryptosporidium* and *Giardia* in drinking water has been suggested as one solution to ensure Sydney's water contamination events do not recur. There have been many suggestions from members of the public, the media and discussion in Parliament urging the Government to impose mandatory levels. Both the medical profession and the water industry have presented reasoned arguments against this approach.

It is obvious that to set an arbitrary standard may not ensure safe water. It may also lead to significant costs without identifiable health benefits.

This chapter considers how standards are set and outlines arguments for the introduction of health and operational water quality standards for *Cryptosporidium* and *Giardia* in drinking water in New South Wales.

How are levels set?

Levels may be defined in different ways and for different purposes. A level may be set for public health purposes. This would derive from a belief that above this level there may be adverse health consequences. It could be stated that when these concentrations are detected, certain public health-related actions should be taken. For example, the water supplier may be required to notify the health agency, which must consider public health responses such as informing the public or issuing a boil water alert.

The alternative would be to set operational water quality standards that provide directions to the water supplier about the operation of the water supply system. This would state that, when *Cryptosporidium* or *Giardia* above a certain level is detected, some actions must be undertaken to improve the quality of the drinking water or protect public health. For example, the water supplier may be required to do any or all of the following:

- commence its incident management regime;
- change its operational management of the plant; and
- undertake additional works such as treatment augmentation, catchment protection or maintenance works to ensure the level is not routinely exceeded.
- The arguments for setting public health-related levels and operational water quality levels are quite different.

Can public health-related levels be specified?

Are public health-related levels set overseas?

World Health Organisation and European Community

The World Health Organisation 1993 Guidelines for Drinking Water do not include any specific regulations relating to *Cryptosporidium* and Giardia. However, they do state that there is no tolerable limit for these pathogens. This implies that the aim is to totally remove pathogens from water supplies.

The European Community (EC) environmental legislation states that water intended for human consumption should not contain pathogenic organisms.

Canada

Canada's national-level health agency publishes Guidelines for Canadian Drinking Water Quality, which are prepared by a Federal-Provincial Subcommittee. The document is intended to apply to all public and private drinking water suppliers as an outline of acceptable parameters and best practice in water quality management. As water is a provincial responsibility, compliance with the Guidelines is not legally enforceable. However, Quebec and Alberta have introduced enforceable regulations that require water suppliers to meet the standards through their operating licence. In Quebec, public notification is required if the water violates microbiological standards. [Decker, KG and Long, BW]

The Canadian Guidelines establish a Maximum Acceptable Concentration (MAC) permissible in drinking water for those contaminants that are deemed or suspected to be harmful to public health. The Guidelines set out concentrations in the water of the contaminants that are not considered to pose a significant risk to health.

In July 1996, the Federal-Provincial Subcommittee released for public comment a document entitled Protozoa in Drinking Water (FPS, 1996), to include *Cryptosporidium* and *Giardia* among contaminants

deemed dangerous to public health. It proposed a MAC of zero viable *Cryptosporidium* and *Giardia* cysts per 1000 litres of water, with a requirement for adequate treatment processes rather than routine monitoring for *Cryptosporidium* and Giardia. The proposed guideline was rejected during the consultation period, primarily because of the concern that water suppliers would be forced to monitor treated water for *Cryptosporidium* and Giardia. The Federal Provincial Subcommittee is currently revising the proposed guideline
(Health Canada, 1996).

New Zealand

In New Zealand, the national-level Ministry of Health has developed the New Zealand Drinking-Water Standards, which outlines maximum concentrations of contaminants acceptable for public health in drinking water systems. The standards are not mandatory, although some of New Zealand's 13 regional councils, which are responsible for drinking water quality, have introduced them into their by-laws.

The 1995 Standards currently classify *Cryptosporidium* and *Giardia* as a Priority 1 risk to public health, along with faecal coliforms. Compliance with Priority 1 requirements involves demonstrating the absence of *Cryptosporidium* and *Giardia* from water supplies. This in effect sets a zero level for *Cryptosporidium* and *Giardia* in 100 litres of treated water.

United States of America

The Federal Safe Drinking Water Act 1974 provides for national primary drinking water regulations in the USA. The regulations, introduced in 1989 through the Surface Water Treatment Rule (SWTR), are administered by the US Environmental Protection Agency (US EPA). The regulations apply to all public water systems using surface water sources or ground water under the direct influence of surface water. The regulations set different standards based on the size of the community potentially at risk. The Interim Enhanced SWTR will apply to water systems that serve over 10,000 people. The final enhanced SWTR, to be introduced in the year 2000, will apply to systems that serve less than 10,000 people and will introduce extra requirements for systems over 10,000 people. The current SWTR regulates 83 contaminants in drinking water. The regulations impose a requirement that drinking water be treated to achieve 99.9% (3 log) removal or inactivation of Giardia. They also set a non-enforceable maximum contaminant level of zero for Giardia, without specifying the volume of water to be examined. The Safe Drinking Water Act requires each owner or operator of public water systems to notify customers of any failure to comply with a maximum concentration level or treatment technique requirement.

In 1994, the US EPA proposed to extend the regulations to include *Cryptosporidium*. To determine the regulation, the US EPA introduced a research program, called the Information Collection Rule, to collect data on the national occurrence of *Cryptosporidium* and *Giardia* in drinking water. Data on raw and treated water was collected from 350 public water systems that together operate 500 treatment plants and serve communities of more than 10,000 people.

Based on this research, the US EPA plans to release a final Enhanced Surface Water Treatment Rule in November 2000. This is likely to introduce a maximum contaminant level of zero for *Cryptosporidium*. It would apply to all public systems that use surface water or ground water under its direct influence. The final SWTR is likely to include:

- stricter catchment control requirements for systems that use surface water and do not want to install filtration;
- periodic sanitary survey requirements for all surface water systems; and
- several alternative requirements for augmenting treatment control of *Cryptosporidium*.

The US Interim Enhanced Surface Treatment Rule is still essentially a turbidity rule that will lower the existing turbidity rules of the Surface Water Treatment Rule and relate compliance to turbidity requirements of 95% of readings less than 0.1NTU. The document, as presently written, does not address how compliance with desired outcomes for parasites is measured in a practical sense ie. for

New Zealand and the USA this is done by either turbidity measurement or credits for appropriate treatment processes.

Are public health-related levels set in Australia?

The 1996 NHMRC guidelines do not recommend an acceptable level of *Cryptosporidium* or *Giardia* in drinking water. They do advise that, if *Cryptosporidium* or *Giardia* is detected, epidemiological or prospective action to control these organisms may be necessary.

The NHMRC Protozoa Working Group, which is revising the 1996 guidelines in relation to *Cryptosporidium* and Giardia, has advised that it will not include in its updated guidelines a numerical level for *Cryptosporidium* and *Giardia* in drinking water. The Group believes that the state of scientific knowledge is not sufficiently advanced to be able to set a level with any degree of rigour.

Are public-health related levels applied to Sydney's water?

Sydney Water is currently not required to meet specified levels of *Cryptosporidium* and *Giardia* in drinking water which are deemed to be unsafe for human health. However, the presence of *Cryptosporidium* and *Giardia* at any level does trigger a specified series of actions under its Incident Management Plan and NSW Health's interim protocol.

NSW Health's Interim Protocol currently states that when testing for *Cryptosporidium* or Giardia, detection of the parasites in treated water "at any level" will trigger Sydney Water (1) undertaking an investigation for potential failures of water treatment and (2) informing NSW Health within one hour. Further, when *Cryptosporidium* or *Giardia* is detected, the Chief Health Officer will consider the need for a boil water alert, or for some other public health response.

Since the initial contamination, Sydney Water publishes readings of *Cryptosporidium* and *Giardia* in the treated water on its Internet site. NSW Health has assumed responsibility for reporting any positive results to the public via the electronic media. I have recommended in Chapter 9 (Public health impacts) that all test results continue to be publicly reported.

Are operational water quality levels set overseas?

Canada, United States of America and New Zealand

In Canada, the United States and New Zealand, maximum levels of *Cryptosporidium* and/or *Giardia* in drinking water have been specified. These levels are also used for operational purposes, and influence the decisions of water suppliers in relation to treatment types and plant operations. This is particularly so in the USA and New Zealand, where compliance with specified levels of treatment is accepted, provided the treatment process is up to the agreed standard.

England and Wales

In England and Wales, levels for *Cryptosporidium* and *Giardia* in drinking water have recently been imposed as triggers for operational actions and public information.

The Drinking Water Inspectorate (DWI), part of the Department of the Environment, has responsibility for ensuring that the 29 water companies comply with the Water Supply (Water Quality) Regulations 1989. The regulations specify minimum monitoring, treatment and public information requirements regarding water quality. They incorporate the parameters of the European Community Drinking Water Directorate though, in some instances, more stringent provisions are imposed. (Drury, et al 1997).

The Regulations currently state that drinking water should "not contain any element, organism, or substance...at a concentration or value, which would be detrimental to public health". Also, section 70 of the Water Industry Act 1991 states that it is an offence to supply water that is unfit for human consumption.

In November 1998, the UK Government announced the introduction of an enforceable standard for regulating *Cryptosporidium*, but not Giardia, in drinking water. The Regulations will give the DWI greater powers to prosecute water companies if *Cryptosporidium* is detected at unacceptable levels.

A breach of the Regulation is a criminal offence which carries a penalty of an unlimited fine.

The standard is based on the level of treatment required for potentially high risk water sources. The standard sets a numerical limit of "an average" of less than one oocyst in 10 litres of water, in samples taken continuously over a 22 hour period using a specified methodology.

Significantly, investigation of all known waterborne outbreaks of cryptosporidiosis in the UK by the DWI has identified that in almost every case there was an alleged specific cause, including post-treatment contamination or failure of some aspect of the treatment plants.

Considerable raw water monitoring has been undertaken across the UK since the large outbreak of cryptosporidiosis in the Oxford/Swindon area in 1989/90. Through this, a large database on the occurrence of *Cryptosporidium* and *Giardia* in UK raw waters has been created. This has enabled the level of one oocyst in 10 litres to be defined as the appropriate standard.

The introduction of the new standard will lead to considerable expenditure for the UK water companies, a cost that will ultimately be passed on to consumers. Initially the cost of additional monitoring was estimated to be in the region of £8 million. The additional costs associated with this extension of the standard have not yet been calculated. In addition to the increase in monitoring costs, it has been estimated that there may be further costs associated with augmentation of the water treatment plants to ensure compliance with the standard. These costs have been estimated to be up to hundreds of millions of pounds.

Should health or operational standards be set?

It is clear that a more informed approach to issuing public health alerts is required, not only in Sydney but throughout the world. This should be developed by better understanding the parameters which need to be assessed when issuing alerts.

There are difficulties in making public health decisions on the basis of detecting only the presence or absence of *Cryptosporidium* and *Giardia* in drinking water. Informed public health decisions need to take into account a range of other factors. These include the likely viability, strain and source of the organisms. However, given the difficulties in determining these factors at the time of initial detection, public health decisions usually need to be made in the absence of this information and must be conservative.

I have canvassed opinion from leading experts both in Australia and throughout the world.

It is obvious from these discussions and recent research that more information, particularly about *Cryptosporidium*, is required before it would be appropriate to provide mandatory health-related standards. We need to understand the issue of viability, infectivity and the behaviour of organisms in particular water bodies and the distribution system before a mandatory health standard could be applied. Significantly, the Bouchier Report released in November 1998 on *Cryptosporidium* in water supplies does not recommend health standards. Instead it proposes a treatment standard based on continuous sampling.

Specifying operational levels

It is clear that the absence of viable *Cryptosporidium* and *Giardia* from treated water supplies is desirable. However it must be accepted that this may not be possible under all circumstances and the UK group of experts who assisted in the preparation of the Badenoch Report acknowledge that *Cryptosporidium* and *Giardia* will occasionally appear in treated water.

Although it is not possible to set a specific level to trigger public health decisions, strong arguments exist for setting a specific performance level for operational purposes. The aim should be to set a water quality performance standard that reflects the best achievable performance of the plant in removing pathogens. This must take into account the condition of the catchment. Appropriate standards could be set which reflect the individual circumstances of the catchment and the treatment facilities. When existing facilities do not meet those standards, upgrades would be required over time.

As noted, neither the NHRMC Guidelines nor Sydney Water's Operating Licence specify levels of *Cryptosporidium* and *Giardia* in the water for operational purposes.

For such an operational level to be workable, I am of the view that it should be sufficiently specific to provide a meaningful guide to the operation of the water distribution system. It should specify the following parameters:

- the **number** of *Cryptosporidium* oocysts and *Giardia* cysts detected;
- the sample **volume**;
- the **frequency** of testing of samples; and
- the detection **methodology** used and recovery efficiency of the testing procedure

The following table shows an overview of how these parameters are applied in the levels set for *Cryptosporidium* and *Giardia* in drinking water in various overseas locations.

	Canada	**United States of America**	**England & Wales**	**New Zealand**
Number	0 C/G[1]	0 G/C[2]	1C	Ø 0C/G
Concentration / Volume	1000 litres	No	10 litres	No
Frequency	No	No[3]	Yes	No[3]
Methodology	No	No[3]	Yes	No[3]

[1] Canada specifies 0 viable oocysts/cysts
[2] expected from 2000 for *Cryptosporidium*.
[3] US and NZ accredit the treatment type and related criteria instead of specifying the testing methodology and sampling frequency.

It is still premature to specify water quality levels which will trigger operational actions in Australia. However, the figures used in the UK provide a useful guide. Assuming that treatment plants can achieve 99.9% (3 log) removal or inactivation of *Cryptosporidium* and Giardia, then the levels required in raw water to result in a breach of the specified level would be 10,000 per 100 litres.

In my opinion water suppliers should be required to endeavour to produce water that is free of viable *Cryptosporidium* and *Giardia* and to develop procedures to minimise the risk of contamination events.

This involves a comprehensive assessment of the likelihood of contamination occurring and the identification of necessary amelioration strategies.

While NSW Health should have the responsibility of making public health decisions, water suppliers must be diligent in assessing risk and taking action to restore water quality when it is impaired. In the longer term, these commitments should be incorporated into revised Operating Licences for Sydney Water.

The proposed UK sampling method which allows averaging over 22 hours rather than grab samples should be evaluated for use in New South Wales.

If found to be reliable, a performance standard should be imposed for each distribution system which incorporates the matters I have identified.

Increase public understanding

The introduction of a mandatory water quality performance level for *Cryptosporidium* and *Giardia* in drinking water may have significant consequences. One consequence may be that water consumers will have to pay more to cover the costs of safer water. There should be an informed public debate to assist the Government in determining the priority the community places on drinking water quality and the likely health risks.

Rural water supplies

My discussions with the Local Government and Shires Associations have highlighted the need for protocols to be developed between NSW Health, Department of Land and Water Conservation, Environment Protection Authority and country water suppliers to ensure effective public health outcomes in all areas.

Conclusions

Significant work is required to assess the implications of imposing an operational water quality performance standard. It is appropriate that water suppliers be given time to evaluate their position and appropriate cost/benefit analysis undertaken before a mandatory operational standard is imposed. I recommend that a process begin immediately to review the consequence of applying an operational standard. The Government should review the position with a view to imposing a standard at the end of 1999. This review should be informed by the work of the NHMRC.

Chapter 12: Monitoring for *Cryptosporidium* and Giardia

Why monitor?

Water suppliers generally institute programs to monitor the quality of the raw and treated water. These programs involve taking water samples at set times from identified locations throughout the system, and testing them for parameters such as turbidity, microorganisms and chemical pollutants.

Monitoring programs are implemented for regulatory, public health and operational purposes. The community is increasingly aware of water quality issues and monitoring is also important to maintain public confidence. Advice to the community on water quality results provides people with an informed basis for assessing water safety. Monitoring programs can provide an early source of information on the presence of contaminants in water. This information can then be used to determine public health responses, including boil water alerts. It can also trigger operational responses such as increases in treatment processes to either remove or inactivate threats. Monitoring is also used to assess the operation of filtration plants against required specifications.

The test results are also used to determine the ongoing effectiveness of catchment management and treatment processes in providing barriers to the risk of contamination in drinking water. The significant cost burdens of monitoring programs are borne by water suppliers and then usually passed on to consumers. This means that monitoring should not be undertaken without justification and clear linkages to public health and operational decisions. In developing a monitoring program for a contaminant, the likely occurrence of that contaminant in the raw water must be assessed. In addition, the performance of water treatment in removing the contaminant should be known. For example, the reliability of chlorination in killing salmonella means that monitoring the operation of the chlorination process is more important than monitoring for salmonella after treatment.

It is also important to develop a database of monitoring results from raw water so background levels of contaminants can be understood. This allows the setting of base levels which, if exceeded, trigger an event which can initiate special operational and/or public health measures such as increased chlorination or boil water alerts.

Raw water monitoring is often more important than treated water monitoring. It constitutes one of the most significant preventative measures to ensure water quality. Results showing increased contamination in raw water may act as the trigger for operational changes which aim to prevent contaminated supplies reaching the consumer.

Treated water monitoring serves primarily as a regulatory check on treatment plant performance. On its own, it cannot be relied on to indicate operational difficulties or public health risks.

The procedures for monitoring *Cryptosporidium* and Giardia are developing rapidly but without general agreement on appropriate methodologies. Expert opinion has concluded that routine monitoring for *Cryptosporidium* in raw water is necessary when there is an identified risk of the parasite occurring in the catchments. However, routine monitoring of treated water for *Cryptosporidium* is not generally recommended. It is normally only undertaken if there is a significant decrease in raw water quality, treatment processes are disturbed, or an outbreak of potentially related illness is reported.

The difficulties in detecting *Cryptosporidium* and Giardia in water mean that the most effective monitoring approach is to use a range of tests which aim to detect both *Cryptosporidium* and Giardia and to focus on identifying any deterioration in raw water quality, which may suggest an increase in pathogens. Sampling programs may also attempt to address the likely clustering of parasites in water, such as taking water from storages at different stratifications or the use of cartridges that can collect *Cryptosporidium* samples continuously.

Public demands for safe drinking water will not be satisfied by the existence of a monitoring regime alone. There must be confidence in the monitoring regime and, in particular, in those responsible for collecting and assessing samples. It is for this reason that I have previously recommended the establishment of an independent laboratory.

What happens around the world?

United Kingdom

In November 1998, the UK Government introduced an enforceable standard for *Cryptosporidium* in drinking water. It requires continuous monitoring of treated water leaving plants where contamination by *Cryptosporidium* is considered a high risk. These are plants which treat surface water with less than seven days bankside storage or groundwaters which may be affected by surface water. The regulations specify that compliance is tested by collecting samples of treated water using a cartridge intended to catch any *Cryptosporidium* oocysts in the water passed through it. (UKDETR, 1998)

United States of America

The US Environmental Protection Agency (US EPA) plans to promulgate an interim Enhanced Surface Water Treatment Rule. This is expected to recommend monthly monitoring of raw water for *Cryptosporidium* and Giardia using 10 litre samples and treated waters using 100 litre samples. Monitoring of water leaving the treatment plant would only be required if concentrations exceed 10 oocysts/cysts per litre or if the total culturable virus concentration exceeds 1 oocyst/cyst per litre in raw water during the first 12 months of monitoring. This proposal was developed on the basis of the data collected through the national monitoring program referred to as the Information Collection Rule. This is providing a substantial information base on the incidence of *Cryptosporidium* and Giardia in US waters (US EPA, 1998).

Canada

The Canadian Guidelines for Drinking Water Quality do not currently recommend routine monitoring for *Cryptosporidium* and Giardia in drinking water. Water suppliers throughout Canada voluntarily monitor for *Cryptosporidium* and Giardia, usually to develop databases on the occurrence of parasites in their systems and to evaluate the effectiveness of their treatment processes in removing them (Clancy, 1998).

New Zealand

Routine monitoring for *Cryptosporidium* and Giardia is not currently required by the New Zealand Drinking Water Standards 1995. Watercare Services Ltd, New Zealand's largest water supplier, undertakes a discretionary monitoring program for *Cryptosporidium* and Giardia that includes monthly sampling of each raw water source and final treated water from each water treatment plant. Incident based monitoring of treated water is triggered when the turbidity of water leaving treatment plants reaches set levels, as specified in the standards. Watercare undertakes no research monitoring at present.

What happens around Australia?

The 1996 National Health and Medical Research Council (NHMRC) guidelines do not specify routine monitoring regimes. Reliance is on tests for organisms that indicate whether water is faecally contaminated. The guidelines recognise that monitoring for specific protozoan pathogens is complex, expensive, time consuming and may fail to detect their presence in water. In updating the 1996 guidelines, the NHMRC Protozoa Working Party is considering appropriate monitoring regimes. It has indicated that the draft revised guidelines may contain clearer directions on monitoring for *Cryptosporidium* or Giardia.

There is no routine monitoring program for *Cryptosporidium* and Giardia in either the Northern Territory, Western Australia or in certain Victorian water supply systems (Yarra Valley, Central Highlands and Gippsland). The West Australian Water Corporation argues, on the basis of project-based monitoring and statewide surveys of surface sources, that its catchment practices negate the need for regular monitoring.

Limited monitoring is undertaken in Tasmania and in the Australian Capital Territory. South East Water, City West Water and Coliban Water in Victoria also have limited monitoring programs.

More comprehensive programs for *Cryptosporidium* and Giardia are conducted by other Australian suppliers. For example, Brisbane Water conducts weekly sampling of its bulk water supply reservoirs. It conducted a project-based monitoring program in 1994-95 and is currently reviewing the adequacy of its routine monitoring program. In South Australia, United Water conducts weekly sampling of its reservoirs, the inlet and outlet of storage facilities and the outlets of its water treatment facilities.

Melbourne Water's routine monitoring program for *Cryptosporidium* and Giardia includes sampling its service reservoirs monthly or quarterly. A project-based monitoring program of the two largest storages was undertaken last year to assess the effect of the storages on *Cryptosporidium* and Giardia levels. Since mid 1997, Melbourne Water has undertaken intensive sampling of raw and filtered waters including 400 samples taken throughout the catchment plus one sample per week in the distribution system.

In NSW, water suppliers' monitoring programs for *Cryptosporidium* and Giardia are varied. For example, Hunter Water Corporation's routine monitoring program includes sampling monthly in raw water, weekly in treated water, and fortnightly in the distribution system. Few local councils currently undertake routine monitoring on a regular basis.

What monitoring does Sydney Water do now?

Sydney Water currently has a more elaborate monitoring program for *Cryptosporidium* and Giardia than other water suppliers in Australia.

Under the Memorandum of Understanding (MoU) with NSW Health, Sydney Water must do the following:

- prepare a comprehensive water quality monitoring plan within three months of the signing of the MoU;

- develop and maintain an effective system of quality assurance for monitoring (sampling and testing) and reporting;
- provide NSW Health with quarterly and annual monitoring results and analysis of a full range of health-related parameters approved by NSW Health;
- provide NSW Health with an annual report evaluating drinking water quality against the requirements of the NHMRC Guidelines;
- prepare and submit to NSW Health an annual water quality improvement plan to address problems identified through regular monitoring;
- prepare an annual publication listing all routine water quality test results; and
- prepare and submit to NSW Health a comprehensive water quality management strategy outlining its current and long term intentions for water supply, wastewater reclamation and public health aspects of wastewater disposal.

NSW Health confirms that, since the MoU was signed in November 1997, Sydney Water has complied with the requirements to produce quarterly and annual monitoring results. An annual report will be submitted evaluating the quality of Sydney Water's drinking water in line with the NHMRC Guidelines. A drinking water quality improvement plan is currently being developed and will be finished in early 1999.

Sydney Water's Water Quality Monitoring Plan was released in February 1998 with NSW Health's endorsement. The Plan includes the following elements.

Monitoring for indicator organisms

Sydney currently monitors for faecal and total coliform more frequently than is recommended in the NHMRC Guidelines. Currently, coliform testing is undertaken in the distribution system at 646 consumer taps on a four-weekly cycle. In addition, there is weekly treated water testing at the outlet to the 11 water filtration plants. Monthly tests are also undertaken at the 202 reservoirs. NSW Health has agreed with this approach.

Turbidity monitoring

Turbidity monitoring may be a useful indicator of treatment failure. Turbidity is monitored continuously at the Prospect plant in both the raw and treated water, at each of the 202 reservoirs and monthly at the 646 sites tested for indicator organisms. Evidence of changes in turbidity at treatment plants triggers further sampling of the treated water. Event-based sampling is also activated by major rainfall events and floods, water filtration plant malfunctions and notified point contaminations.

Monitoring for *Cryptosporidium* and Giardia

The current Water Quality Monitoring Plan requires six samples of water taken from customers' taps, in each supply system, to be analysed for *Cryptosporidium* and Giardia each year. In June 1998, Sydney Water increased its monitoring for *Cryptosporidium* and Giardia, with NSW Health's endorsement. The new Plan for *Cryptosporidium* and Giardia includes:

- fortnightly raw water sampling at each plant's inlet (except for Greaves Creek and Linden water filtration plants where sampling is monthly, given the small populations they serve);
- bi-monthly treated water sampling at each plant's outlet (except for Greaves Creek and Linden where sampling is every three months); and
- monthly monitoring of three major inflows into Warragamba and the inflows into the Wingecarribee River through to the Upper Nepean dams.

Project monitoring

Sydney Water is currently conducting specific monitoring programs of potential sources of *Cryptosporidium* and Giardia in the hydrological catchment. This involves monthly sampling over an

18-month period of identified high-risk sites such as Murphy's Crossing on the Wollondilly River and Kelpie Point on the Coxs River.

A specific monitoring plan has been introduced at the Prospect plant as a result of the recent contamination events. This includes daily monitoring of the filtered water leaving Prospect.

How is Sydney Water changing its monitoring regime?

Sydney Water's current Water Quality Monitoring Plan has been reviewed. A new Plan has been developed and endorsed by Sydney Water, NSW Health and the Environment Protection Authority (EPA). I have also endorsed the Plan.

In developing the Plan, different regimes were recommended for the Prospect plant, in view of the size of the population it serves, and the other water filtration plants supplying Sydney. There is a useful body of data about the occurrence of *Cryptosporidium* and Giardia in the catchments supplying Prospect. It is clear that *Cryptosporidium* and Giardia are present in the Warragamba catchment, where a large number of point and diffuse sources of *Cryptosporidium* have been identified. The Prospect plant supplies water to 80% of the population of Sydney, underpinning the seriousness of any contamination passing through this plant. The Prospect plant uses direct filtration to remove particles, including *Cryptosporidium*, from raw water. This is a single step removal process, which if it fails, may not remove *Cryptosporidium* effectively. These factors mean that it is appropriate for a more stringent monitoring program to be implemented.

There is insufficient data available for Sydney's other water treatment plants. At least two, Warragamba and Orchard Hills, have experienced operational problems and may require frequent monitoring at least until these problems have been resolved. Assessments of each of the individual plants need to be performed prior to developing a definitive monitoring program. This is also true of other water suppliers in NSW.

Assessment of individual water sources and treatment facilities is critical to the prevention of contamination incidents. These assessments will determine meaningful monitoring levels for the water suppliers to cover all risk factors, including the quality of the catchment, treatment plant performance and integrity of the distribution system. This will ensure the most efficient use of resources.

Sydney Water's revised Water Quality Monitoring Plan has four components:

- provisional monitoring;
- routine monitoring;
- event and research sampling; and
- identification of research needs.

Provisional Monitoring Program

This element of the Plan is intended to help restore public confidence in the quality of Sydney's supply system. The Provisional Monitoring Program significantly increases the frequency of sampling at Prospect.

Daily samples would be taken at the following locations:

- Warragamba storage (3 depths);
- raw water source for Upper Canal;
- Warragamba pipelines 1 & 2;
- Upper Canal Prospect;
- inlet to Prospect;
- outlet of Prospect plant;
- outlet of Orchard Hills plant;

- outlet of Warragamba plant;
- inlet of Macarthur plant; and
- outlet of Macarthur plant.

The samples taken from the Warragamba pipeline, the inlet to the Prospect plant, the Upper Canal at Prospect and the inlet of the Macarthur plant would be analysed daily and the other samples archived. If *Cryptosporidium* and Giardia is detected in raw water, archived samples may be immediately tested to protect public health.

It is recommended that the majority of the treated water samples be archived for one month. These can be analysed later if required. As outbreaks of cryptosporidiosis may occur from infections contracted up to 10 days beforehand, archived samples can be valuable.

Every second day, the raw water and treated water at the other water filtration plants should be sampled (that is, Cascade, Greaves Creek, Illawarra, Woronora, Nepean and North Richmond, and Linden when it is operating).

Werri Berri Creek, downstream of the unsewered the Oaks/Oakdale township, and Wingecarribee Water Filtration Plant (when operating) are to be sampled every eight days. The Wollondilly River at Murphy's Crossing and the Coxs River at Kelpie Point would be sampled every four weeks. These samples would be archived, but not analysed at the time, unless necessary.

In addition, certain events should be accompanied by sampling and immediate analysis including: starting or stopping the sourcing of water from the Upper Canal; changing screen locations or outlets at dams; and water flowing from Doodle's Folley Creek when the Glen Quarry cut is open. The EPA should be consulted on when water downstream of each of the nine sewage treatment plants (Bowral, Goulburn, Mittagong, Lithgow, Moss Vale, Berrima, Bundanoon, Wallerwang and Mount Victoria) should be sampled.

The Provisional Monitoring Program should also include a trial of methods for continuously analysing large volumes of water for *Cryptosporidium* and Giardia. In particular, the sampling methodology introduced in the UK to continuously monitor *Cryptosporidium* in treated water should be trialed for its future application to Sydney's water, including validating the Corning or Genera cartridge filters to assess their validity in concentrating 1000 litres of finished water.

The Provisional Monitoring Program should operate for a maximum of six months. A review should be conducted after three months. After the six-month period, the suitability of methods for analysing large volumes of water, including cartridges, should have been assessed. The Routine Monitoring Program, described below, can then be instituted, incorporating any changes indicated from the assessment of these methods.

Routine Monitoring Program

The Routine Monitoring Program applies when only background levels of *Cryptosporidium* and Giardia are likely to be found. This would normally coincide with dry weather conditions.

The main aims of routine monitoring are:

- to characterise numbers of the parasites in each raw water storage area under dry weather conditions;
- to refine monitoring needs based on variations in numbers and sample volumes required for satisfactory detection outcomes;
- to identify potential problem waters to assist in catchment management; and
- to provide data for microbial risk assessment.

The Routine Monitoring Program will provide for continuous sampling of raw water at dam offtakes for turbidity and temperature, indicating changes in water quality. Twenty litre samples for

Cryptosporidium and Giardia and one litre samples for total coliforms, thermotolerant coliforms and spores of Clostridium perfringens will be taken daily. The value of monitoring the latter on a daily basis needs to be evaluated. The locations to be sampled are the Warragamba pipelines 1 and 2, and the Upper Canal at the junction to Prospect's Channel 2. These sites represent the raw water supplied to the Prospect, Warragamba and Orchard Hills plants.

Water will be sampled at the inlets of the Macarthur, North Richmond, Cascade, Woronora, Greaves Creek, Linden, Nepean and Wingecarribee plants. Again, sample size will be 20 litres for *Cryptosporidium* and Giardia and one litre for coliforms and spores. The frequency of inlet sampling will be based on the results of sampling during the Provisional Monitoring Program. In addition, overall assessment of the likelihood of a contamination event will affect the sampling frequency.

There will be daily sampling of filtered water at Prospect using 1000 litre samples. The Orchard Hills, Warragamba, Illawarra, Woronora, Macarthur and North Richmond plants will be sampled at least weekly.

Event and research sampling

The aims of the event and research sampling are to better understand:

- the impact of wet weather events on numbers of oocysts and cysts in raw waters;
- the impact on parasite numbers of other catchment events such as sewage treatment plant overflows;
- the role of storage areas such as lakes in the behaviour of the parasites, including hydrological modelling information; and
- the overall operation of the water supply system, integrating the monitoring results with catchment, storage and treatment management.

Monitoring for research purposes will include a thorough investigation of possible problem areas within catchments. The first stage is to evaluate and confirm possible sources of contamination. Investigations to date have identified a number of potential sources that should be sampled in the catchments supplying the Prospect plant. Subsequent surveys will indicate repeat sampling requirements and identify any potential new contamination sources.

An Event Monitoring Program will also be implemented. Monitoring of raw and filtered waters will be undertaken at water treatment plants when:

- raw water turbidity significantly increases. For plants operating off reservoirs, the event program is triggered when turbidity reaches 5 NTU in the raw water or 0.1 NTU in the filtered water. For other plants, it will be triggered by 100% increases in turbidity.
- treatment plant performance changes. For example, when there is decreased performance in particulate removal, or following major changes in plant settings;
- parasites are detected above the upper 80th percentile for raw water; or
- NSW Health identifies the potential of waterborne disease in the community.

When an event is triggered, treated water will be continuously monitored using 1000 litre samples, with 20 litre raw water samples, for the duration of an event. This assumes that a suitable methodology can be identified for analysing large volumes of water. In addition, catchment investigations will be undertaken to ascertain the reason(s) for increases in turbidity or microbiological indicators.

NSW Health will be notified immediately of the presence of oocysts or cysts in filtered or distribution waters. Information should also be provided on the accuracy of the analytical results, including any confirmation by DAPI staining.

Identification of research needs

A panel should be established to review the ongoing effectiveness of the monitoring plan. The panel should also identify further research needs. This panel should include representatives from Sydney Catchment Authority, Sydney Water, NSW Health, and the EPA.

Chapter 13: Incident management

What are Sydney Water's incident management procedures?

Sydney Water's incident management procedures at the time of the recent events were contained in three documents:

- Corporate Incident Management Policy and Standards;
- Drinking Water Quality Incident Management Plan; and
- Memorandum of Understanding between Sydney Water and NSW Health.

Corporate Incident Management Policy and Standards

This outlines policies and principles to guide development of incident management plans across the organisation. The policy is very general and essentially a statement of commitment rather than an operational and strategic framework for incident management.

Drinking Water Quality Incident Management Plan

This Plan contains specific guidelines for the management of drinking water quality incidents. It includes a list of contaminants and the concentrations which trigger a routine, significant or major incident.

For *Cryptosporidium* and Giardia, the detection in raw water of more than one and less than 100 oocysts/cysts per 100 litres triggers a routine incident; more than this triggers a significant or major incident. In filtered water, 1 oocyst/ cyst of *Cryptosporidium* or *Giardia* per 100 litres triggers a significant incident; more than this triggers a major incident. Other factors such as raw water quality changes, treatment works malfunction or an increase in background levels of illness may also trigger a declaration of an incident.

The Plan states that the Sydney Water Incident Manager should only initiate a significant or major incident in consultation with the Managing Director.

The Plan provides a useful guide to operational actions by including triggers, responsibilities and action checklists. The triggers for significant events are consistent with those in NSW Health's Interim Protocol (that is, one or more oocysts/cysts of *Cryptosporidium* or *Giardia* per 100 litres of treated water). However the effectiveness of the document in an emergency situation is questionable as it is lengthy, complicated and difficult to follow.

Memorandum of Understanding with NSW Health

This outlines agreed procedures for communication and coordination between Sydney Water and NSW Health. It requires Sydney Water to immediately report to NSW Health any event within water supply and wastewater systems which may have significant implications for public health. Both parties are required to nominate a 24-hour incident management contact point for the coordination of responses to such an event. The Memorandum of Understanding (MoU) also requires Sydney Water to prepare and demonstrate to NSW Health its preparedness for contingency, emergency and disaster responses for Sydney Water's drinking water supply and other systems.

The recent events highlighted the need to improve the coordination of incident management between the two organisations. NSW Health and Sydney Water have responded by increasing the obligations in the MoU.

What is best practice in incident management?

Best practice models for incident management have the following characteristics:

- a foundation of organisational commitment;
- an overall command structure which addresses both operational response and strategic issues management within an integrated framework;
- processes that ensure information flows which support decision-making and coordination of skills to provide an integrated response;
- robust operating procedures which provide clarity of roles, responsibilities and actions;
- adequate facilities to manage an emergency or crisis event;
- effective management of relationships with external stakeholders such as customers, the media, government, regulators and contractors; and
- regular training and exercises.

(Marsh and McLennan, 1998)

Incident management in the United Kingdom

There have been 25 outbreaks of cryptosporidiosis associated with the consumption of drinking water in the United Kingdom since 1989 (Bouchier, 1998). As a result, water authorities have had considerable experience in developing, implementing and reviewing incident management procedures.

Incident management procedures in the United Kingdom are supported by legal obligations including mandatory notification of health and other relevant authorities of contamination events, and criminal liability for providing water which fails to meet regulatory standards or is unfit for human consumption.

It is mandatory under the Water Industry Act 1991 for water companies to notify the relevant authorities of events and incidents. This notification rule applies to any event that is likely to give rise to a significant risk to consumers but also to events that may be of national significance, have attracted publicity or may have caused significant concern to consumers. An incident is an event or series of events when the quality of drinking water demonstrably deteriorates.

In addition to these requirements, water companies have been encouraged to comply with the recommendations of the Expert Group on *Cryptosporidium* in Water Supplies, which has produced three reports since 1990 (Badenoch, 1990, 1995 and Bouchier, 1998). The reports of the Expert Group emphasise the importance of effective incident management procedures involving water utilities, health authorities and local authorities. The reports also emphasise the need to regularly review and rehearse plans, particularly in view of changing organisation structures and personnel.

Although not all water companies in the UK have incident management procedures that include all these recommendations, many are now standard practice. The key features of one company's incident management plan is outlined as an example of good practice in this field:

Best practice model

- an asset owner (for example, the water treatment plant manager) and drinking water quality manager, who work by roster and are responsible for drinking water quality around the clock;
- these managers are responsible for notifying the relevant authorities of relevant events and incidents;
- separate event and incident procedures are documented and include event management which is designed to prevent escalation to an incident and to ensure that all parties are rapidly notified by circulating details to all managers and technicians;
- events are classified into four levels depending on the level of containment possible, and incidents are classified according to the seriousness of the problem and the number of customers affected;

- an event controller, usually an asset owner or a qualified technician, is automatically appointed when an event is declared. He/she is responsible for all decision making and is able to draw on appropriate technical advice;
- the event controller is supported by a 24-hour Event Support Centre which is responsible for all communications within and outside the company. Its role is to track, log and overview the event and coordinate communication. A separate customer centre deals with all customer matters;
- a director takes over in a level four event as multi-agency involvement becomes more likely and an outbreak control team, led by a health authority, may be established;
- when an incident is declared, an Incident Management Team is established and an Incident Manager appointed who is accountable to the company for all actions taken. The team manages every aspect of an incident and all communications, internal and external to the company;
- all key staff keep a detailed written log of their activities, actions and decisions and the reasons why; and
- exercises are run occasionally to test and review the systems in place.

What changes should be made to Sydney Water's incident management procedures?

Findings of the Inquiry's Second Interim Report

In my Second Interim Report on the Management of the Events, I noted that the contamination incident was the first time that many of Sydney Water's staff had been involved in a major incident and that many aspects of their response were appropriate. These included a number of operational actions such as rapid mobilisation of staff, shutdown of the Upper Canal, flushing, reservoir dumping and disinfection procedures.

I also identified a number of communication problems which indicated weaknesses in the incident management procedures of both Sydney Water and NSW Health. These included:

- poor communication between Sydney Water and NSW Health, for example, delays in notifying NSW Health that the incident had moved from being localised to a potentially system-wide event, and problems in agreeing on the issue of appropriate press releases;
- communication problems within Sydney Water between management and technical/operational staff. Insufficient consideration was given by management to technical staff views on the likely dispersion of contamination within the system;
- poor communication within NSW Health which delayed notification of very high levels of *Cryptosporidium* and *Giardia* to an appropriate decision-maker;
- communication problems between Sydney Water and the operators of the Prospect plant. For example, there was a lack of effective exchange of information on the operation of the Prospect plant and of Sydney Water's data on the raw water entering Prospect. This impeded early development of a cooperative approach to identifying the source of contamination and effective remedial action;
- poor communication between Sydney Water and the Minister, including considerable delay in informing the Minister of the first contamination event; and
- poor communication with the public, for example delays in informing the public of the possible extent of the contamination and conflicting information on precautions to take.

I noted that these problems were partly due to failure of the relevant written documentation to provide a clear and comprehensive guide for action in such events. I emphasised the importance not only of improving written procedures but also ensuring that staff are trained and are drilled in carrying out procedures.

Sydney Water's response

Following the contamination events and the findings of the Inquiry's Second Interim Report, Sydney Water commissioned a review of its incident management plans. The plans were evaluated against a

best practice model which drew on the documentation and experience of a range of major organisations in Australia and overseas.

The review identified many examples of excellence within Sydney Water, both in incident preparedness and response, including good operational response plans, and recognised the commitment and dedication of staff during recent months.

The review found that, despite the best efforts of many people involved in the incident management program, there was no clear overall structure for managing incidents that sets out in one place the framework, procedures and checklists for action. While the review commended the operational response to the recent water contamination events, it found that strategic and corporate crisis response was inadequate. For example, there was no clear guidance on communication with external stakeholders such as government, regulators and media.

To address these weaknesses, the review developed recommendations which have been endorsed by Sydney Water's Board of Directors. Sydney Water is currently developing an implementation plan, including revisions to the written documentation and comprehensive incident management training. I strongly support this development.

Revisions to the MoU with Health

In response to the findings in my Second Interim Report, Sydney Water and NSW Health have revised the terms for incident management in the MoU . The revised MoU includes new requirements for Sydney Water and NSW Health to jointly develop an incident management plan and conduct joint training exercises for personnel from both organisations and water treatment plant operators. It also increases Sydney Water's obligations to provide information to NSW Health in the event of an incident.

Other changes made to the MoU include increased requirements to provide test results to regulatory agencies, a strengthening of the formal consultation structures between Sydney Water and NSW Health, and a requirement that Sydney Water quality assurance procedures are implemented to a standard required by NSW Health.

I endorse these changes to the MoU. I understand that when revisions to the MoU are completed, it will be placed on public exhibition for 30 days before being finalised.

Conclusions

I strongly endorse the actions of Sydney Water and NSW Health to improve their incident management procedures and processes. Sydney Water has undertaken a comprehensive debriefing process following the contamination incident and taken action to ensure that the lessons learnt will be applied in the future. Implementation of the recommendations of the review and the revised MoU should significantly improve the organisations' capability and preparedness for managing future incidents.

Chapter 14: Future improvements to the system

There is general agreement that the most effective approach to keeping *Cryptosporidium* and *Giardia* from a water supply is to adopt a multiple barrier approach. This usually involves minimising *Cryptosporidium* and *Giardia* entering water courses, managing storages to retain water as long as possible so settlement and die off are maximised, treating water using a number of treatment processes, and maintaining distribution systems to prevent contaminants entering or building up in the pipes and hydrants.

Sydney's water supply, through the Prospect plant, has long term storage in Warragamba dam combined with in-line filtration. In normal climatic conditions this provides two barriers to *Cryptosporidium* and Giardia.

The recent contamination events have demonstrated that a number of operational improvements can be made to increase the effectiveness of these barriers.

Many of these improvements have been proposed by the Joint Action Group. The group's report provides a useful analysis of the events and detailed recommendations for future development work in water storage and treatment. I commend the report to the Sydney Catchment Authority for its consideration and recommend that it be made available to all interested individuals and organisations.

Each of the improvements described has a significant capacity to enhance drinking water quality and involves relatively minor operational expense.

I am of the view that the implementation of these improvements will, if taken together, be more cost effective than any of the suggested options for augmenting the Prospect plant. The Prospect plant appears to be functioning well within contractual parameters and upgrading it cannot presently be justified. The one exception is the possible treatment of the backwash water.

I recommend that the following improvements to the drinking water system be implemented as a priority.

Improvements in catchment management

The most effective element in the multiple barrier approach to water quality is effective catchment management. Every effort should be made to prevent contaminants, including *Cryptosporidium* and Giardia, from entering catchment waters.

No level of treatment should be relied upon to counter the impact of continually deteriorating raw water quality. It is prudent to assume that the current threat posed by *Cryptosporidium* and *Giardia* to drinking water may be mirrored by other pollutants as they become recognised. Public expenditure on drinking water protection must give priority to either eliminating or controlling the identified threats to the raw water.

We must accept that the Warragamba catchment is presently compromised and will deteriorate further, unless action is taken to prevent further degradation and to address existing sources of contamination. Although Sydney's catchment will never be pristine, it can be managed to diminish the risk of contamination by *Cryptosporidium* and *Giardia* and other pollutants.

I made recommendations about the future management of the catchment in the Third Interim Report. Of particular importance were the recommendations with respect to catchment management which the Parliament has now implemented by establishing the Sydney Catchment Authority and providing a Regional Environmental Plan with strict controls on future developments in the catchment.

I stress again the importance of creating an accurate picture of the condition of the catchment. A research program is required to understand and rank the risks posed by the identified diffuse and point sources of *Cryptosporidium* and *Giardia* as well as other water pollutants. This is essential for developing the remedial and preventative on-ground actions required as part of a broad catchment protection strategy. The following actions, among others, will be required:

- enhancing the capacities of sewage treatment plants in the catchment;
- accelerating the program to sewer urbanised areas close to Warragamba dam (especially The Oaks and Oakdale to reduce the contamination draining into Werri Berri Creek);
- measures to address pollution from intensive agricultural industries;
- measures to minimise cattle faeces entering water courses, especially in the Inner Catchment; and
- investigation of the potential effects of biosolid application in the catchment.

The priorities for the necessary actions will be determined by the outcomes of the research program. The likely contribution of each action to reduce the magnitude and frequency of contamination of water courses by infective *Cryptosporidium* and *Giardia* must be considered, together with the cost and timeframe for implementation.

The cost of catchment protection actions will be substantial. An indicative estimate for upgrading and improving the efficiencies of the nine major sewage treatment plants in the catchment to achieve no bypasses or overflows for 10 year storm events is $11.6 million. Sydney Water's program to sewer The Oaks and Oakdale is estimated at $22 million. Catchment protection actions will also take some time to implement. However, it is clear that protecting the catchment is more effective and cost-efficient than enhancing the other safety barriers. I recommend that research on catchment protection measures be accelerated and that the Sydney Catchment Authority decide, as a priority, on a program of remedial and preventative catchment protection works.

Development and maintenance of an information database

Sydney Water gathers a great deal of data. It includes gathering time series data in the catchment (meteorological data, gauging station data, automatic sampling). There is also in situ data (thermistor chain data, water quality samples), data from treatment plants (flow, quality) and data from the distribution system (flow, quality). These data are augmented by "enquiry" driven data and data gathered irregularly for specific objectives. The data is mainly gathered by AWT.

Sydney Water has numerous gauging stations on various tributaries within the catchments. These gauging stations probably measure in excess of 40% of the river flow, numerous physical parameters such as temperature, pH, salinity and oxygen. They are also the sites where numerous samples are taken at regular intervals for standard biological and chemical analysis. The information is extensive but does not seem to be well coordinated and does not appear to be being used in management decisions relating to the catchment as a whole.

The Sydney Catchment Authority and Sydney Water will require sufficient technical and scientific capacity to ensure the integrity of routine data collection programs, and the design and implementation of process data collection. They will need to carry out validation modelling and scenario modelling.

This will require the construction of integrated models commencing with Gauging Information Systems, catchment modelling, river modelling and lake modelling. Sydney Water has commenced work on these, but much needs to be done.

Improvements in management of the storages

Water storages, such as Warragamba dam, are the second element of the multiple barrier approach and can naturally remove *Cryptosporidium* and *Giardia* before water enters filtration plants. If water is stored for extended times, parasites may die off or be locked into sediment as they settle on the lake bed. Poorly managed storages, however, can create conditions in which oocysts and cysts cluster at certain temperature zones within the lake. Concentrations of the parasites can then be rapidly transported and fed in clusters through the intake point to the filtration plant, presenting the filtration plant with a slug of highly contaminated water.

The performance of storages in retaining water and allowing particles to settle depends on natural occurrences such as the local climate (wind, rainfall) which affects each lake's thermal conditions. However, other factors affecting contaminated raw water can be controlled to some extent by storage management.

Attempts can be made to dilute contamination within the catchment by utilising flows from dams and weirs, particularly in high-risk areas. The level at which water is drawn from the dam wall into the pipes to the filtration plant can be varied to avoid thermal levels in the lake where the parasites are suspected to cluster. The water flowing into the lake and in the lake itself can be mixed, using bubblers to separate any *Cryptosporidium* and *Giardia* clustering at particular thermal levels and to introduce oxygen at depth. The water level of the storage can be regulated by releasing excess water at various levels rather than allowing it to spill.

Examination of overseas events and swimming pool contamination in Sydney reinforces the need to maximise the time from when the oocysts leave the host and are ingested by a recipient. Most

contamination results from direct contact with fresh faecal matter and some human strains of oocysts are now thought to die quite rapidly. This phenomenon may account for the lack of disease in Sydney despite the unprecedented levels of organisms recorded. Any future strategy in managing the water supply should attempt to maximise the time water is held in storage.

The application of the science of limnology and the use of hydrological modelling in Sydney is insufficiently advanced to allow these management actions to be undertaken with a high degree of certainty. However, it should be pursued. I have been advised that effective dam management can decrease the concentration of *Cryptosporidium* and *Giardia* occurring in raw water by a factor of 1,000 (Prof Jorg Imberger, Chairman Centre for Water Research University of Western Australia).

Some storage management decisions have already been implemented, on an experimental basis, to manage *Cryptosporidium* and *Giardia* contamination of Warragamba Dam. They have proved effective. For example, during the recent contamination events, Sydney Water storage managers altered the offtake level at the dam wall and avoided contaminated water.

Work is currently under way to investigate the thermal and hydrological conditions operating in Warragamba dam. This will help determine the optimum strategy for lake management in the future. I recommend that management actions for optimising storage performance, based on this research work, should be implemented as a priority.

Use of Prospect reservoir

Another component of effective storage management is the use of alternative storage areas when the primary storage is discovered to be heavily contaminated. Currently, most of Sydney's drinking water is sourced from the storages at Warragamba dam and the four Upper Nepean dams. If one or more of these storages are found to be significantly contaminated, it should be possible to increase the amount of water from the storages where contamination levels are low or non-existent. During the recent contamination of Warragamba dam, the amount of water coming from the Upper Nepean dams was increased so less water could be taken from Warragamba. This situation was reversed after the rain events in August when the Cataract dam became heavily contaminated.

Prospect reservoir, adjacent to the Prospect plant, could possibly be used to supply the plant with raw water when the water from Warragamba is polluted by *Cryptosporidium* and *Giardia* or another contaminant such as toxic algal blooms. The reservoir is currently offline but its reinstatement as a temporary supply source for Prospect should be considered.

Sydney Water has indicated that the reservoir's infrastructure has been upgraded and, with further enhancements to the existing pumping station that links the reservoir with the plant, it will have an operating storage of 13,270 megalitres. In combination with the supply from the Upper Canal, which has a 680 megalitre capacity, this could provide sufficient raw water to supply Sydney for between 8 to 13 days when Warragamba's raw water is contaminated. If a temporary coagulant dosing facility was installed at the inlet to Prospect reservoir, this time could be extended.

Treated backwash from the Prospect plant has been pumped into the reservoir since early August. I believe this practice should cease and Prospect's backwash water should be further treated and returned to the head of the works.

The benefits of using Prospect reservoir in this manner could be significant in reducing contamination levels.

I have been advised that use of Prospect reservoir as a temporary supply storage, at times of possible contamination, could commence within 12-18 months. Before this, an environmental risk analysis and review must be undertaken and discussed with the Environment Protection Authority. This should be investigated as a matter of priority.

Management of the Upper Canal

The Upper Canal takes raw water from the Upper Nepean dams to the Prospect plant. It is a large channel, partly underground but mostly open to the air and traversed by numerous stock crossings. As it runs through land used for agricultural activities, there is potential for faecal contamination of the water. I recommend consideration of covering parts of the Upper Canal that are most exposed to contamination risks.

Until this is completed, I recommend that the use of Upper Canal water be carefully monitored and managed appropriately during heavy rain events.

Improvements to optimise the performance of the Prospect plant

Australian Water Services (AWS) is required by its contract with Sydney Water to meet a set of water quality criteria and objectives. The criteria include ensuring turbidity of not more than 0.5 NTU in treated water and complying with other requirements set out in schedule 10B of the contract and remaining parameters of the 1987 NHMRC guidelines other than bacteriological criteria (AWS Contract 1993, Schedule 10B). A list of water quality objectives also applies to the Prospect plant. It must be capable of achieving these objectives, although compliance is not mandatory. These include turbidity of less than 0.3 NTU and zero total and faecal coliforms in treated water (AWS Contract 1993, clauses 5.1 and 10.4, Schedule 10A).

Schedule 10 to the contract was published in my Fourth Report.

Detailed investigations into the current treatment regimes at the Prospect plant have highlighted the desirability of requiring the plant to maximise its potential to produce clean water. Measures which could be taken include:

- ensuring that a turbidity standard of 0.1 NTU, as is currently achieved, is maintained;
- continuing to optimise the coagulant dosing;
- introducing on-line particle counters to more closely monitor performance; and
- shortening filter runs.

The Prospect plant has been operating within optimum parameters since early August and this incurs additional costs. If the plant is to continue to run to optimise coagulant dosing and to shorten filter runs to achieve minimum turbidity levels it may be necessary to revise the existing requirements with AWS. The existing contract provides for upgrades and I recommend that these measures be implemented to ensure that Prospect can operate to provide the highest level of protection within the existing infrastructure.

Treating the backwash

The filters at the Prospect plant are regularly backwashed to clean them. Backwash water represents about 3% of the plant's daily output. It is dirty with accumulated floc and other particles such as algae, *Cryptosporidium* and Giardia. Before the recent contamination events, the backwash water at the Prospect plant was treated by coagulant dosing prior to being placed in a thickener to settle out sediments. It was then returned to the head of the plant, to be mixed with the raw water and undergo the treatment process. Since early August the backwash has been discharged to Prospect Reservoir to decrease as much as possible the contaminant load on the treatment processes.

Returning the backwash to the head of the plant carries the risk of increasing the concentration of *Cryptosporidium* and *Giardia* in the raw water, and placing a further strain on the filtration process. It has been estimated that returning the backwash without treatment can contribute a further 12% to 18% in the concentration of *Cryptosporidium* and *Giardia* reaching the filters.

International best practice accommodates the re-use of backwash water when it has been properly treated to ensure that any contaminants are removed to an acceptable level. This has the benefit of maximising the use of a commercially significant volume of water and avoiding difficulties in disposing of contaminated and untreated water. The Environment Protection Authority has indicated

that untreated backwash will not be allowed to be discharged to the Prospect Reservoir in the future. Discharging untreated backwash water to the sewer is not likely to be feasible.

Options for further treating the backwash water, prior to returning it to the head of the plant, include deep bed filtration or ozonation.

Installing an ozonation capability for the backwash waters at the Prospect plant would cost $10 million for capital and $700,000 in annual recurrent expenditure. This is equivalent to about $2.00 extra per annum per property supplied from the Prospect plant. However, ozonation is not recommended. Although it is likely to inactivate *Cryptosporidium* and Giardia, it does not remove the deactivated *Cryptosporidium* and *Giardia* oocysts/cysts from the water. This means that when monitoring is carried out on the treated water, *Cryptosporidium* and Giardia, although deactivated, will still be apparent.

The alternative is to treat the backwash water with deep bed filtration. This could be provided at a cost of $9 million capital and $0.45 million per annum, the equivalent of about $1.50 to $1.70 extra each year per property supplied from the Prospect plant. I recommend that this be done. Although enhancing backwash treatment is not likely to produce large increases in plant performance, it would provide an additional barrier and will reduce contaminant levels to some extent, particularly during heavy contamination backwash.

Possible improvements via treatment augmentation

The terms of reference provided to me by the Government requested that I determine whether current arrangements for water treatment are appropriate. After considering the submissions and the advice of experts, including the work of the Sydney Water/Australian Water Services joint action group, I do not believe there is any justification for augmentation of the treatment process beyond treating the backwash.

There are three options for treatment augmentation that have been recommended to me. They are:

- membrane filtration;
- disinfection by ozone or ultraviolet light; and
- a combination of particle removal and disinfection enhancement.

Membrane filtration provides nearly complete removal of particles. Ozonation uses ozone which breaks down to form reactive oxygen species which act as a disinfectant. Ultraviolet light also works as a disinfectant by causing breakage in the nucleic acid, thus preventing cells from being infectious.

Particle removal measures could be combined with disinfection enhancements. The most useful of these would be post-ozonation followed by Granular Activated Carbon (GAC) contactors which absorb organic micro-pollutants and taste and odour compounds.

The installed cost of introducing these different options has been estimated for Prospect as follows.

Annual cost benefit analysis of process options

Treatment	Log Reduction	Capital Cost	Recurrent	$/Household
		$000	Cost $000	pa
Pre-ozonation	2 log (99%)	150,000	10,000	24.9-28.3
Post-ozonation + GAC	3 log (99.9%)	300,000	17,000	47.1-52.1
Membranes	6 log (99.9999%)	550,000	37,000	91.7-100.2
Membranes + GAC	6 log (99.9999%)	600,000	42,000	101.5-111.5

Obviously each option is expensive. I do not believe this expenditure can be justified. I believe that effective catchment management and better utilisation of storages with improvements to the operational performance of Prospect are to be preferred.

Furthermore, membrane filtration and ultraviolet disinfection have only been used in relatively small plants. Their application, at this stage of their development, to one of the largest plants in the world would carry significant risk. The associated infrastructure has not been developed and maintenance and operational issues would be significant. A detailed cost benefit analysis would be needed before it could be considered.

Treatment by ozonation and ultraviolet would inactivate the parasites but would not remove them from the water system and current testing will not allow their viability to be determined. The difficulties involved in introducing appropriate public health responses would remain.

I accept that this position will need to be regularly reviewed as more information is obtained about raw water quality and Prospect's capacity to produce water that meets the required standard.

Improvements to the distribution system

The distribution system must be maintained to prevent contaminants building up in the pipes and hydrants. Although Sydney Water has suggested that *Cryptosporidium* and *Giardia* do not survive for appreciable periods in the distribution system, I am not at present persuaded that this is the case. Sydney Water should continue to maintain a regular flushing program to remove sediments and biofilms and improve the aesthetic quality of the water.

A comprehensive improvement package

A wide range of other possible improvements to the drinking water system have been submitted to me. I have listed them below and recommend they be included in future research and planning to be undertaken by Sydney Water, Australian Water Services and the Sydney Catchment Authority.

A most important suggestion has come from the water industry. It has suggested that quality assurance procedures, such as those used in the food industry, should be used as a framework for guiding water quality protection. This approach, which is applied through systems such as ISO 9000 and Hazard Analysis Critical Control Points (HACCP) can be readily incorporated into the water industry. HACCP, for example, focuses on identifying critical control points within the system and establishing monitoring procedures to track critical process targets and triggers. Applying this to water treatment, critical points such as raw water quality, coagulation, filtration and where appropriate disinfection, would be carefully monitored.

As I have indicated (in Chapter 12), I believe that monitoring is a critical part of the water supply system. I have recommended that monitoring, particularly of raw water throughout the catchment and in water storages, should be improved. In particular, monitoring is important to ensure that the improvements which I have recommended produce the anticipated water quality benefits.

In Australia, the water industry has begun developing a system of water quality management which will incorporate quality assurance principles. This system promotes a holistic approach to water quality management by critically evaluating individual water systems to develop strategies to control, reduce and eliminate identified hazards that occur throughout the system. It is a preventative approach to public health protection, ensuring that every step in water production is protected by a series of safeguards.

I endorse the work being undertaken to develop this approach. It will provide a useful guide for water suppliers on how to optimise resource allocation for drinking water protection.

Other important work which has been identified includes:

- continuing review and testing of coagulation performance over varying raw water quality and flow conditions;
- process studies to examine mobilisation and transport of contaminants including protozoa, viruses and algae pesticides through the catchment and lake system;
- upgrading the catchment and lake models for Warragamba dam and implementing similar models on other Sydney Water catchments to study impacts of changes in land use, specific sources of pollution and possible effects of climate change;
- detailed three-dimensional modelling of the lake to study the travel paths of contaminants, based on the current three-dimensional Sydney Water model to examine issues such as dilution of contaminants, full or partial destratification and optimisation of withdrawal strategy; and
- installation of on-line particle counters at the water filtration plants to provide additional information on the effectiveness of filtration for particle removal. These could also be used to signal treatment malfunction. Initially, on-line particle counters should be installed on the raw water and selected filter effluents at each water filtration plant (eg. two per plant) and one filter on each module for Prospect, with additional counters available for rotation to confirm the performance of additional individual filters. If further investigation shows that particle counters are a reliable, accurate and useful method of control then they could be considered as an adjunct to turbidity, headloss (lowered efficiency of filtration) and time for backwash control for individual filters.

Laboratories providing parasite analyses should be accredited by National Association of Testing Authorities (NATA). This will take some months to achieve as NATA has yet to implement a performance monitoring approach to the enumeration of parasitic protozoa or hire appropriate staff to assess environmental parasitology laboratories. It is strongly recommended that an approach similar to that implemented by the US EPA for the Information Collection Rule be used by NATA. Laboratories would only be accredited if their analysis of performance samples lies within set limits and if laboratory management and procedures are approved.

Chapter 15: The contract

Introduction

My report on the Prospect Water Filtration Plant tender process and contract arrangements was prepared using my powers as a Royal Commissioner. It is the Fourth Report of the Inquiry.

On 21 October 1998 the original Inquiry was constituted as a Royal Commission under the Royal Commissions Act 1923 to investigate:

"(1) the process of calling and evaluating tenders and awarding the contract for the construction of Prospect Water Filtration Plant; and
(2) the preparation and terms of that contract".

The Letters Patent required these matters to be examined to the extent relevant to the following Terms of Reference of the original Inquiry, which required me to:

"(v) determine whether the current arrangements for water treatment are appropriate; and
(vi) determine who is responsible for the current arrangements and whether their actions were appropriate".

Concern about the contamination of the water supply occurred first in the system that is sourced through the Prospect Water Filtration Plant. Accordingly, my original Terms of Reference required me to investigate the contract for that plant. Subsequently the Terms of Reference were widened, but I did not examine the contracts for the other three plants for which the Water Board tendered at the same time as Prospect. This would have required major inquiries beyond the scope of the Fourth Report. However, the general selection process for each contract was examined.

The Fourth Report identified the persons responsible for the current arrangements for the Prospect plant and examined whether their actions were appropriate. It also discussed the question of the

suitability of the current water treatment arrangements in the context of removing or inactivating *Giardia* and *Cryptosporidium*. This matter has been further considered in this Final Report, which provides recommendations for the future treatment of the water supply. The present state of scientific knowledge in relation to *Cryptosporidium* and *Giardia* makes this issue complex and difficult.

Background to the Prospect Water Filtration Plant

The Water Board contemplated water filtration as far back as the 1960s. In fact, provision was made for water filtration when Warragamba dam was built. However, there was no capital available to construct the facility and Prospect reservoir was believed to be doing an appropriate job as a settlement basin.

Prospect reservoir's effectiveness was being seriously compromised by the late 1980s. Massive doses of alum were required in the water to reduce turbidity, especially during storm events. The system was beginning to feel the strain, and complaints about drinking water quality were emerging.

There were also increasing indications from publications of the National Health and Medical Research Council (NHMRC) and the Australian Water Resources Council (AWRC) that desirable water quality would require stricter standards. The 1987 NHMRC/AWRC guidelines confirmed the need to address the quality of Sydney's water. Further guidelines which would impose a stricter regime were expected in 1993. In fact these guidelines were not published until 1996.

My inquiries reveal that the Water Board began to consider *Cryptosporidium* and *Giardia* in about 1986. The matter was not considered particularly significant in the Sydney context, although it was believed that a general improvement in water quality was necessary. To advance this improvement, a Drinking Water Program (DWP) was developed in the late 1980s. This was one of a number of programs setting out the long term objectives of the Water Board. The other programs were the Clean Waterways Program, the Water Resources Program and the Urban Development Program. The DWP was designed to ensure that the Water Board improved Sydney's drinking water by meeting the relevant NHMRC/AWRC water quality guidelines. One of the strategies to achieve this was the development of four new water filtration plants to be known as Prospect, Macarthur, Woronora and Illawarra.

The difficulty for the Board was finding ways to finance the necessary capital works. There was insufficient capital to finance all of the identified programs. This problem was solved when policies were developed within Government to make greater use of private sector funds for building and operating public infrastructure. The filtration plants were originally intended to be provided under the Build Own Operate Transfer (BOOT) policy but this ultimately changed to Build Own Operate (BOO) due to taxation and financial considerations. Under the BOOT policy the plants would have been transferred to the Board at the end of the contract period. However, under the BOO arrangements the infrastructure is not automatically transferred. The development of the facilities by the private sector was not without controversy within the Board.

Tenders for the Prospect Water Filtration Plant

The Board called for Expressions of Interest for the four plants in April 1991. These were evaluated and Invitations to Tender were issued to five pre-qualified parties in February 1992. This resulted in three tenders for Prospect.

The Expression of Interest and tender process was scrutinised rigorously and I am satisfied that it was undertaken with integrity.

The rigour of the early stages of the tendering process continued through to the selection of the preferred tenderers. I am satisfied that this was done with honesty and without interference from any inappropriate source. However, some aspects of the selection process require comment.

NSW Water Services Pty Ltd was selected as the preferred tenderer for the Prospect plant. This company was a subsidiary of Australian Water Services Pty Ltd, which ultimately negotiated the

contract for the Prospect plant on behalf of a partnership of companies comprising Lyonnaise (Prospect) Pty Ltd, P&O (Prospect) Pty Ltd and Lend Lease Water Services Pty Ltd. I have referred to both NSW Water Services Pty Ltd and Australian Water Services Pty Ltd as AWS throughout this report.

The packaging decision

The tender process for the Prospect Water Filtration Plant was conducted in conjunction with tenders for the Macarthur, Illawarra and Woronora Water Filtration Plants. Prospect was by far the largest. The Board decided that the projects should be packaged so that competition would be preserved throughout the tender process and to avoid the Board being vulnerable to one private sector operator. It was also seen as important that the smaller less lucrative plants, such as Woronora, should be addressed as well as the larger more commercially attractive plants such as Prospect. Accordingly, the Board decided that the four water filtration plants should be packaged into three projects (Prospect, Macarthur and Illawarra/Woronora) and whoever succeeded in the Prospect tender would not be able to contract for any of the others.

This decision was made known to the tenderers with the tender documentation. The exclusion of the successful Prospect tenderer from being able to being able to contract for either of the other projects had the potential to inhibit the Board from achieving a fully competitive tender process. In fact, AWS shrewdly assessed the position and determined to tender only for Prospect, thereby enhancing its chances of success.

As it happened, AWS offered the lowest price for the Prospect plant. When analysed appropriately, it offered a price which over the 25-year term of the contract had a net present value that was $40 million less than the nearest tender price offered by the Wyuna consortium. At the time AWS was selected as the preferred tenderer, it had not proved its treatment process to the satisfaction of the technical assessment team of the Board. In particular, its mono media sand filter had not been able to meet the Board's minimum test run target of eight hours for turbid raw water. In response to this problem, AWS offered a guarantee that it would use anthracite which was the alternative filter medium proposed by the Water Board in its concept design, if the proposed sand medium could not meet the Board's test run target. Although AWS did eventually prove its sand filter process to the Board's satisfaction, the Board took a significant risk in appointing AWS as the preferred tenderer for the Prospect plant.

The Board's process of selecting the preferred tenderer was concerned more with obtaining the lowest price than ensuring the highest quality technology. Mr David Manzi, an engineer and the Drinking Water Program Manager who was responsible for the tender process, tells me that the technical evaluation assessment was only required to determine whether the tendered processes were acceptable and could meet the Board's requirements. The Board's selection process did not give additional weighting to tenderers who could provide superior technology. This potentially meant that the Board was prepared to compromise the extent to which the tender process could deliver substantial technological improvements.

Water Board studies on *Cryptosporidium* and *Giardia*

During the time the water filtration plant proposals were being developed, the Board again considered the issue of *Cryptosporidium* and Giardia.

In March 1992 the Board commissioned a report from Aquatech Pty Ltd, environmental and water management consultants, which reviewed the published information on *Cryptosporidium* and Giardia. It concluded that until proven otherwise, the Board should consider all raw water sources to be potentially contaminated with *Cryptosporidium* and *Giardia* and take appropriate decisions on treatment protocols. This was an important document. It recommended further investigation into the efficacy of various disinfection options and the installation of laser particle sizing instrumentation. It also recommended that the Board should not rely on compliance with turbidity requirements for treatment plants but should place emphasis on continuous monitoring of filter effluents to detect sudden changes in turbidity and particle counts.

The Scientific Services Unit of the Water Board (later Australian Water Technologies Pty Ltd Science & Environment Division) also commissioned work in the catchment to determine whether *Cryptosporidium* and *Giardia* were a problem. This work, undertaken by Dr Primrose Hutton, revealed levels of *Cryptosporidium* which were considered to be of health concern and some evidence of Giardia. It also attempted to identify an appropriate efficiency standard for the removal of pathogens and identified the need for further study. Hutton's findings demanded urgent consideration as part of the water treatment proposals. The report was available by October 1992.

These reports were obviously known to the Scientific Services Unit and to the engineers responsible for the DWP tender process. However, the Hutton report was not given to the Board's Environmental Management Unit (EMU), which was responsible for assessing the environmental impact of the projects, until March 1993.

The environmental planning and assessment process

The relevant provisions of the Environmental Planning and Assessment Act 1979 required the Water Board to prepare environmental impact statements (EISs) and consider the environmental consequences of the proposals before deciding whether or not to proceed. As I have indicated, the EMU was responsible for the environmental assessment process. Although I am satisfied the EMU carried out its task with rigour, some of the engineers responsible for the DWP did not always appreciate the obligations the Environmental Planning and Assessment Act imposed on the Board.

It is important that this issue should be seen in context. The Board undertook the design and tender stage of the Prospect project before publishing an EIS. It chose a preferred tenderer with whom it proceeded to negotiate a final contract before a Determination had been made that the project could proceed under the Environmental Planning and Assessment Act. It was most unlikely that a decision would have been made that the project should not proceed after a preferred tenderer had been chosen. By the time the environmental process was finalised, the Board was under time cost pressures imposed by the preliminary contractual arrangements.

The antipathy of some of the engineers to the environmental assessment process is evidenced by their dealings with the environmental scientists and is particularly emphasised by the fact that the Hutton report on *Cryptosporidium* and *Giardia* was not given to the EMU as soon as it became available. This conduct was inappropriate, considering the potential importance of these organisms to the safety of the drinking water.

It is clear that the Board's DWP engineers in 1993 had an incomplete understanding of *Cryptosporidium* and Giardia, their consequences for human health and the effectiveness of the filtration plants in dealing with them. The engineers were concerned that, as information about *Cryptosporidium* and *Giardia* became available, this did not delay the development of the filtration plants because of the general deterioration in the quality of the water. This was a legitimate concern. The early release of the information may not have altered the course of subsequent events, but would have allowed better informed decisions.

When the report was made available, the EMU expressed concern about whether or not the proposed filtration plants were appropriate for the treatment of *Cryptosporidium* and Giardia.

There was also concern within the EMU about the return of the backwash supernatant (the water produced by backwashing the filter beds) to the head of the works. The original intention was to dispose of backwash waters to the Prospect Reservoir. This was denied, quite properly, by the Environment Protection Authority as Prospect is categorised as "Class S Specially Protected Waters" and could not receive backwash from the plant. The disposal of the backwash was linked with the possible problem of *Cryptosporidium* and Giardia. If organisims could build up in the backwash water they could break through the filters of the plant.

Prospect plant's capability

Manzi's answer to whether the proposed Prospect plant would remove pathogens was that the engineers believed overseas experience had shown that such filtration plants would remove 99.9% (3 log) of pathogens, including *Cryptosporidium* and Giardia.

Although there was some evidence to support the view that (by a combination of removal and disinfection) the proposed filtration plant would deal effectively with Giardia, the same conclusion was not appropriate for *Cryptosporidium*, having regard to the available information.

The EMU accepted Manzi's advice. A discussion of this matter was included in the Prospect plant clause 64 report which incorporates the Water Board's Determination of the matter under the Environmental Planning and Assessment Act, and provides conditions for its implementation.

The final form of the clause 64 report

The language of the clause 64 report is unclear. The report required the backwash supernatant to be disinfected unless it could be shown that recycling this water to the plant inlet would not affect the attainment of 99.9% (3 log) overall removal or inactivation by the plant. Clause 2.2.4.4 provides as follows:

"(a) The Water Board will require the water treatment company to return the filter backwash supernatant to the head of works after being treated by disinfection, unless disinfection can be shown to not be required to the satisfaction of the Water Board's Manager Bulk Water, to ensure removal of pathogens so that the overall treatment process ensures a minimum 3 log removal or inactivation (99.9%) of pathogens (7.7.3).
(b) The Water Board will continually review the management of filter backwash supernatant and ensure that best available technology economically achievable is adopted at the Prospect WTP (Water Treatment Plant) as better information becomes available on pathogens in drinking water (7.7.3)."

I am satisfied that the Managing Director, Mr Bob Wilson, made plain to Manzi and the environmental scientists of the EMU that he required the treatment process to effectively remove all *Cryptosporidium* and Giardia. He also contemplated some future modification of the plant, if necessary, to achieve this. Whether he directed that the contract for the Prospect plant should contain an obligation for AWS to remove or inactivate 99.9% (3 log) of pathogens is unclear. The clause 64 report was determined by his successor, Mr Paul Broad, who does not appear to have been aware of the previous consideration of the issue.

Clause 2.2.4.4 is expressed as a modification relating to the backwash waters but also describes the overall efficiency of the plant. In my view the draftsman intended to include a requirement on the plant for 99.9% (3 log) removal or inactivation of pathogens. However, I doubt whether the wording chosen was effective to impose this obligation.

The Prospect contract

AWS was advised of the clause 64 report. The draft contract provided for the requirements of the clause 64 report to become contractual obligations and AWS became concerned that clause 2.2.4.4 may impose a performance standard on the plant. It responded by confirming that the plant had not been designed to "ensure minimum 3 log removal or inactivation (99.9%) of pathogens." This was correct, for the plant had been designed before *Cryptosporidium* and *Giardia* were believed to be a problem in Sydney's catchments. The negotiations concentrated on who was to pay for any disinfection of the backwash water should this be required. I am satisfied that it was never intended by Manzi, or the other engineers of the DWP who were responsible for the negotiations, that AWS would be obliged by contract to remove or inactivate 99.9% (3 log) *Cryptosporidium* and Giardia. The engineers assumed that the contractual requirements for turbidity would adequately deal with the removal of pathogens.

Recent information indicates it is likely that the plant is removing or inactivating 99.9% (3 log) of *Cryptosporidium* and *Giardia* in most circumstances, in particular when the water is dirty and likely to

contain higher levels of pathogens. Work is being undertaken with the prototype plant to confirm whether or not this is so. There are indications that on occasions the plant will not achieve this level.

An examination of the events surrounding the contract reveals some problems with the assessment of the project under the Environmental Planning and Assessment Act. The provisions of Part 5 of that Act are designed to ensure that decisions on major Government projects are taken after consideration of all relevant environmental matters. The environmental assessment process is intended to assist the decision making process of the Board, including the choice of appropriate technology. This is made difficult when the project itself will be defined by the tenderer who wins the contract. However, I doubt there is any practical alternative. Obviously the project which the Board would prefer to implement must be the subject of an environmental evaluation. In this case, because the parameters for efficiency of the plant had been defined at the tender stage, the desire of the EMU to include a performance standard for *Cryptosporidium* and *Giardia* in the environmental Determination caused difficulties and could not have been carried through to the contract.

A great deal has been learnt about *Cryptosporidium* and *Giardia* and water treatment since 1993, particularly during the recent events. If 99.9% (3 log) removal or inactivation of pathogens had been imposed as a requirement under the contract, it would have been difficult to audit compliance. It would not have been effective as a contractual term. Accordingly, the fact that 99.9% (3 log) removal or inactivation was not imposed as a contractual term is of no practical consequence. If the Water Board had required AWS to achieve 99.9% (3 log) removal or inactivation, this would have led to a far more expensive plant. It was appropriate for the Board to require the turbidity levels indicated in the contract but, on the evidence available at the time, additional expenditure on water treatment would not have been appropriate.

The Water Board did impose obligations on AWS to achieve defined maximum levels of turbidity and other potential contaminants in filtered water. These levels were assumed to be an appropriate means of defining water quality. The levels chosen were appropriate, having regard to the contemporary circumstances.

Improvements to the Prospect plant

In chapter 14 of this report I discussed possible future improvements to the treatment process at the Prospect plant. These include more rigorous performance standards for turbidity, optimising coagulant dosing, shortening filter runs, introducing on-line particle counters to monitor performance and requiring further treatment of the waters produced by backwashing the filters.

The existing contract provides for upgrades to the plant. Under clause 17, Sydney Water may at any time give notice to AWS, requesting it to upgrade, expand or alter the plant, or to change its treatment processes. It may do so for any reason, but the contract specifically contemplates such a request due to various causes, including Sydney Water "desiring or being obliged to change the quality of treated water it provides to its customers".

AWS is obliged to comply with any such notice, subject to any necessary approvals and licences being obtained. After receiving a notice AWS must promptly submit an outline of its proposed works and a timetable. It must later notify Sydney Water of the details of the proposed works, consequential changes to performance standards, proposals for financing and changes to the availability and usage charges payable to it by Sydney Water.

After receiving AWS' response to its notice, Sydney Water must either notify its acceptance or inform AWS of the matters to which it does not agree and set out its alternative proposals. If no agreement can be reached, the contract provides for resolution by arbitration.

The contract acknowledges that AWS is entitled to recover all reasonable costs incurred as a result of carrying out an upgrade or change in treatment process, including any consequential change to operating costs and financing costs, together with a "reasonable rate of return on those costs having regard to current market conditions and the additional risks (if any) undertaken by AWS".

Although the contract provides for adjustment of the availability charge and daily usage charge as a consequence of an upgrade or change in process required by Sydney Water, it does not necessarily follow that these charges will be increased unless AWS incurs additional expense.

Communications between the contract parties

The contractual arrangements between Sydney Water and AWS requires a high level of co-operation and communication between the parties.

This is recognised by the contract, which contains a number of provisions dealing with communication and co-operation between the contracting parties. For instance, clause 2.3(a) requires that the parties co-operate to achieve the objectives of the contract and the performance of each party's obligations. Each party is also required to carry out its obligations under the contract with reasonable promptness, unless the contract provides otherwise (clause 2.4).

The contract requires that AWS operate the plant in accordance with Good Operating Practices. This includes taking reasonable steps to satisfy the needs of Sydney Water in operating its water supply system, as communicated to AWS by Sydney Water or as known by the plant manager (clause 10.1). To this end there is to be regular communication and close liaison between Sydney Water and AWS to ensure a continuous sharing of information regarding the water supply system and Sydney Water's requirements for clean treated water. The various operational protocols and manuals which have been developed as part of the contractual arrangements are intended to facilitate understanding and communication between the parties about the operation of the plant.

Although I am satisfied that overall there is a good working relationship between Sydney Water and AWS, in the events that have occurred it has been made clear to me that communications between Sydney Water and AWS are not always effective.

It is fundamental to the successful operation of the Prospect plant that there that there be effective communication between Sydney Water and AWS. The Prospect contract has another 23 years to run. Effective communication between the parties is even more important in the circumstances which occurred recently, not merely to satisfy contractual requirements, but in order for both Sydney Water and AWS to satisfy their obligations to provide clean safe drinking water to the people of Sydney.

Secrecy surrounding the contract

The contract contains elaborate provisions to preserve the secrecy of certain information which was evidently viewed as commercially sensitive by the parties.

Clause 22 provides that, without consent of the other, no party to the contract is to divulge information to any person (including employees, other than on a need to know basis), or to make public statements, concerning clauses 15 (charges payable by Sydney Water to AWS), 16 (arrangements for payment), 20 (insurance requirements) and 21 (liability and indemnities). This prohibition also applies to the schedules to the contract, which contain important information including:

- raw water criteria (the quality of water Sydney Water must provide to AWS);
- water quality criteria and water quality objectives for treated water;
- water quality testing regimes;
- formulae for calculating the availability charge and the daily usage charge payable by Sydney Water and the adjustments to be made if AWS fails to meet the performance standards and
- payments to be made on transfer of the plant to Sydney Water.

All exhibits (apart from the EIS Determination report, which is exhibit 7) are also confidential. These include the quality assurance plans for the plant, preliminary commissioning program and incident management plan, the environmental management plan outline, the operating and maintenance manuals outline and the Prospect operational protocol.

The confidentiality provisions also extend to a range of collateral documents in relation to the Prospect contract, including the Government guarantee.

When disclosure is to be made to a third party, the party making the disclosure must first get the third party to enter into a confidentiality agreement, following the form set out in a schedule to the contract.

I appreciate that there may be valid commercial reasons to protect some details of the contract. It can be argued that disclosing the details of contractual arrangements may inhibit potential contractors from tendering for public infrastructure projects.

However, these interests must be balanced with the public interest in having information relating to protection of public health. In these circumstances, the entitlement of the public to know contractual details must prevail over private commercial interests. I consider that the water quality performance standards for the Prospect plant are a matter of legitimate public concern and I have published them in my Fourth Report.

Sydney Water is liable under the contract to pay an availability charge and a daily usage charge to AWS for the treated water it provides. Although there may be a commercial interest in not disclosing these details, I consider that there is an overriding public interest in the information being available. I have not published the formulae for calculating these charges in my report, but I recommend its release, after consultation with the parties to the contract. I also consider that the terms of the Government guarantee of Sydney Water's should be available to the public.

Chapter 16: The research agenda

During the course of this Inquiry it has become evident that the science concerning *Cryptosporidium* and *Giardia* is relatively immature and the available tools for monitoring, treatment and management of the parasites in drinking water are inadequate.

It is apparent that there are a number of areas where knowledge is lacking. In an attempt to deal with some of these matters, the meeting of the UK National *Cryptosporidium* Research Steering Committee held on 19 October 1998 proposed a broad research agenda. Key topics included:

- development of operational monitoring tools to improve the detection of the rapid influence of surface waters on the quality of groundwaters;
- development of procedures to allow treatment plant operators to better detect conditions which allow oocysts to pass through filters, and evaluation of declining filter rates for oocyst removal;
- further evaluation of continuous sampling techniques, oocyst viability and effects of disinfection, and
- use of seroepidemiology (levels of prior exposure measured by antibody levels in the blood) to assess the impact of improved water treatment on community exposure to *Cryptosporidium*.

Significant research is also being undertaken in the USA and Europe into testing procedures, viability and genotyping of the parasites and treatment methods.

I have had discussions with many individuals and organisations in this area both from Australia and overseas. There are many areas of agreement on the future research needs of the industry. I have also identified some specific needs for Sydney. I do not intend that Sydney Water carry out work in all of these areas but have sought to identify the issues which need to be addressed over time.

Understanding the organisms and the testing methods

Quality Assurance

In my Third Report I referred to the lack of agreement between laboratories on testing results and the possibility of errors. I am advised that this is not unusual. Many well-respected laboratories in the US

were shown during studies by the US EPA and others, to incorrectly identify organisms as *Cryptosporidium* and *Giardia* or to fail to detect them. Clearly, if monitoring for *Cryptosporidium* and *Giardia* is to be useful, there must be confidence in the test results.

In the US and UK there are Quality Assurance schemes which allow laboratories and their customers to assess the performance of the analytical process. While these schemes are not mandatory, many laboratories participate. Until now, the National Association of Testing Authorities, Australia (NATA) has not accredited any Australian laboratories for the performance of tests for *Cryptosporidium* and Giardia. This is because of the uncertain nature of the test methods and the small numbers of laboratories performing these tests.

During this Inquiry, I have met with representatives from NATA and discussed the difficulties of assessing laboratories and of providing a Quality Assurance scheme for *Cryptosporidium* and Giardia. NATA have agreed to implement a program of accreditation for laboratories performing tests for *Cryptosporidium* and Giardia. In addition, it is committed to providing a Quality Assurance program to help laboratories assess their performance. Such a program must be implemented carefully and cannot be rushed. Nevertheless, NATA are progressing as rapidly as possible towards these aims which should give those using *Cryptosporidium* and *Giardia* test results more confidence in the tests themselves and the laboratories performing them.

I am advised that the implementation of a Quality Assurance program is no substitute for adequate Quality Control within a given laboratory. Accordingly, NATA will advise laboratories on adequate internal Quality Control for tests for *Cryptosporidium* and Giardia.

Testing methods

There has been much discussion about a suitable testing procedure for the detection of *Cryptosporidium* and *Giardia* in water. There are many procedures in use around the world and indeed within Australia. It is unclear which of these methods, if any, is reliable. However, in order to be able to assess new methods of detection, it is desirable to have a "reference method" against which other methods can be assessed.

There are no candidate technologies for this at present in Australia, although two methods have recently been proposed overseas which may serve this purpose. The first is the US EPA method 1622 which is designed for small volumes of water (10-20 litres) while the other is the UK method for examining large volumes of treated water. Method 1622 has been extensively validated in the USA and UK and should be suitable for small volumes of water in Australia. The UK method has received less attention but it may be useful for large volumes of treated drinking water.

Both these methods should be evaluated alongside methods used in other laboratories including AWT. Appropriate side-by-side comparisons will identify the most reliable methodologies. This approach should be adopted nationwide to determine the best analytical procedures for Australia. This could be overseen by NATA. It is clear that the design and interpretation of the research must be conducted by an independent body.

AWT have already adopted the confirmatory procedure for *Cryptosporidium* and *Giardia* based on DAPI staining. This approach should be more widely adopted.

The issue of viability

During the recent events, it remained unclear whether the *Cryptosporidium* and *Giardia* present in the water supply were alive or dead. This is an important issue in view of the high levels of organisms reported and the lack of observable health effects. A special test was applied to some samples (the FISH test) which NSW Health had been told would discriminate between live and dead *Cryptosporidium*. The validity of the test has yet to be determined. However, the test shows promise and validation efforts should be encouraged, since an effective test would be extremely useful for management of water supplies.

There are a number of other studies under way in other parts of the world to develop tests to discriminate between live and dead *Cryptosporidium*. Progress on these should be monitored carefully.

The issue of the viability of *Giardia* has received relatively little attention. While it is certainly not of the same priority as the viability of *Cryptosporidium*, research in this area would advantageous.

Specific detection of C. parvum

C. parvum is the only species of *Cryptosporidium* thought to infect man. However, there are no widely accepted tests that can detect this species alone. A number of tests have been suggested but all require further validation. Research in this area may be useful in preventing false alarms due to the detection of other species of *Cryptosporidium* or indeed other organisms not within the genus *Cryptosporidium*. Such a test might be a confirmatory test rather than a primary test.

Genotyping of *Cryptosporidium*

Methods are being developed to differentiate between different strains of C. parvum. These methods appear to be able to distinguish at least two forms; one which infects animals and humans, and the other which infects humans only. The robustness of these methods for water samples needs to be addressed. Tests with the ability to distinguish between strains in this way are useful in attempting to determine the source of any contamination event and have the potential to guide catchment management. It is important that such tests continue to be developed.

Catchment and dam management

Events in Sydney have demonstrated the need for a much better understanding of the parasites in the catchment including source, transportation, impact of environmental conditions and behaviour in rivers and dams. Better understanding of these processes will allow improved catchment management through identification of high risk periods, management of water flows, destratification of storages and hydrological manipulation of water received by treatment plants.

Necessary studies include:

- identification of sources and seasonal factors which might impact on life cycle in hosts, such as cattle/sheep and native fauna;
- susceptibility of the parasite to environmental conditions;
- the development of reliable high recovery, high volume continuous sampling techniques for raw and treated water;
- a structured and systematic program of contaminant monitoring in streams, sediment and lakes to assess frequency, intensity and duration of protozoa inflows;
- a data integrity assessment program for protozoa as well as temperature, conductivity, flows, and nutrients
- the contribution of biosolids to *Cryptosporidium* and *Giardia* in the environment;
- process studies to examine mobilisation and transport of contaminants including protozoa, viruses, algae and pesticides through the catchment and lake system;

- upgrading the catchment and lake models for Warragamba dam and implementing similar models on other Sydney Water catchments to study impacts of land use change, point source impacts and possible effects of climate change; and
- detailed three dimensional modelling of the dam to study inter alia contaminant travel paths to examine issues such as dilution of contaminants, full or partial destratification and optimisation of withdrawal strategy.

Treatment

Treatment research needs to focus on the development of cost effective methods which provide the best water quality production while minimising risks from treatment processes. Major areas include a better

understanding of the impact of existing treatment processes on parasite removal, enhancement of treatment systems through new chemicals and optimisation of current practices, and the development of new treatment processes.

The need for upgrading the knowledge base in this area has been demonstrated by two issues arising from the intensive scrutiny of current treatment methods in Sydney. The impact of chlorination on shedding of particles from filters and the effect of pH levels on the coagulation processes and differing behaviours between live and inactivated parasites had not previously been recognised. Research in this area is being conducted by AWT and should continue.

Some specific research directions include:

Raw water diversification

- determine the treatability of various mixtures of raw water;
- determine quality and operational limitations of high volume withdrawal from Prospect reservoir;
- determine the feasibility of coagulant dosing to Warragamba and Upper Canal waters to Prospect reservoir from both a technical and environmental standpoint; and
- determine any pre-treatment and mixing optimisation requirements of Upper Canal and Prospect reservoir waters to Channel 2.

Plant operation

- better understanding of the interaction between oocysts and coagulants used to optimise removal;
- trial particle and cysts and/or oocyst removal/inactivation on backwash waters using deep bed media filtration and ozonation;
- further investigation of particle counters and streaming current detectors for plant optimisation and control plus monitor world trends; and
- determine the differing properties of inactive and live pathogens and how these relate to water treatment processes.

Plant upgrading

- carry out further investigations of any added benefits that might be gained by installation of a filter to waste system during filter ripening;
- trial the performance of new UV disinfection technologies and membrane technology; and
- trial pre-ozonation and post-ozonation performance with regard to pathogen inactivation and disinfection.

Health

A number of significant research projects are being undertaken in the public health area through the Co-Operative Research Centre for Water Quality and Treatment (CRCWQT) in Adelaide.

The goal of the program is to assess the public health consequences of drinking water quality. Specific studies include:

- the water quality study this randomised double blinded trial is designed to determine whether microorganisms in Melbourne's drinking water are contributing to gastroenteritis in the community. Analysis of faecal specimens will indicate the frequency of *Cryptosporidium* infection relative to other infectious causes of gastroenteritis;
- case-control studies of *Cryptosporidium* in Melbourne and Adelaide these studies will provide information on risk factors for *Cryptosporidium* in two cities with contrasting types of water supplies. Risk factors to be examined include drinking water, recreational water activities, food, childcare, contact with animals and travel;

- case-control studies of cryptosporidiosis in homosexual and bisexual men in Melbourne and Sydney risk factors to be examined will be similar to those above, with the addition of specific questions on sexual behaviour. Both HIV+ and HIV- men will be included;
- the early detection of outbreaks of waterborne gastroenteritis the first stage of this project reviewed current surveillance mechanisms for gastroenteritis in Australia and overseas, and assessed the utility of existing data sources to improve sensitivity and specificity. The next stage will apply the computerised analysis technique of neural network modelling to develop software to analyse trends in surveillance and water quality data and flag unusual variations which may signal outbreak situations;
- a comprehensive quality assurance approach to water quality effective ongoing means to protect public health in Australia require the adoption of a preventative, quality assurance approach that ensures all steps of water production are subject to rigorous quality controls and continuous improvement programs. This will ensure that every step in water production is protected by a series of safeguards and that variations from normal conditions are detected in a timely manner which allows an appropriate response before the problem impacts on the consumer. This project is being carried out in collaboration with the risk assessment group of of the University of Alberta in Canada;
- educating the public there is a need to provide better information to the public to place the risks of *Cryptosporidium* infection in perspective with other illnesses, and explain the difficulties in assessing the risks associated with oocysts in water supplies. The CRCWQT has initiated a project to compile information on *Cryptosporidium* and *Giardia* and other water quality topics, and to produce material to provide a comprehensive public education program.
- studies into gastrointestinal illness - NSW Health is planning to introduce a major study into gastrointestinal illness in NSW and the possible role of pathogens in drinking waters. Any approach to research into the parasites should recognise that the majority of cases are acquired via routes of transmission other than drinking water contamination events**.** Research efforts should not be diverted from efforts to prevent the transmission of *Cryptosporidium* in swimming pools and other recreational waters, or the transmission of *Giardia* in childcare, which are more common methods of transmission;
- epidemiology and enhanced testing methods - management of public health risks posed by the parasites would be significantly improved by the introduction of enhanced testing methods for their presence, species, strain and viability. In addition, the epidemiology of human and animal infection with the various genotypes of *Cryptosporidium* and *Giardia* needs to be investigated with sensitive and reliable methods of detecting and identifying the species and genotypes of *Cryptosporidium* and *Giardia* involved.

The role of the distribution system

There has been considerable discussion on the role of the distribution system during the recent events. There have been suggestions that *Cryptosporidium* and *Giardia* may have become deposited in the sediments and biofilms in the distribution system. Sydney Water does not accept this but believes further evidence is required before a final view can be formed. However, there is evidence including some very recent results which suggests that *Cryptosporidium* and *Giardia* may interact with biofilms and accumulate over time.

There is also evidence that *Cryptosporidium* and *Giardia* may become trapped within sediments in the distribution system where they accumulate. Two areas of further research are clearly required. The survival of *Cryptosporidium* and *Giardia* in distribution water should be investigated. The questions of how long these organisms remain detectable and how long they are viable should also be examined.

The other important question is whether *Cryptosporidium* and *Giardia* are generally present within the Sydney Water distribution system. Samples should be taken from the water distribution system at various points. These samples should be analysed for the presence of *Cryptosporidium* and Giardia. This may not be easy as the organisms are difficult to detect when there is other solid matter present. It may be necessary to develop appropriate detection methods before the work can be effective. In conducting this research, Sydney Water must involve NSW Health. If *Cryptosporidium* and *Giardia* are found in the distribution system, this may not be cause for concern and NSW Health may need to form a view which has regard to the specific circumstances of any positive findings.

CRCWQT has commissioned research to undertake a number of studies within distribution systems. These include:

- the interaction of water flow and water quality, biofilms and pathogens in pipes and service reservoirs is being studied experimentally to determine how these factors affect the health-related and aesthetic dimensions of water quality at consumers' taps;
- instrumentation is being installed in distribution systems to test the chlorine decay models which have been developed. Major projects in the Melbourne and Adelaide systems are proceeding; and
- a study of the potential of *Cryptosporidium* oocysts to accumulate in pipe biofilm and subsequently be released to the water phase by biofilm sloughing has commenced.

Managing research and development in the future

The focus on Sydney Water's commercial operation and the adoption of a "back to basics" approach has reduced the agency's involvement in and resourcing of environmental and health related issues. I am strongly of the opinion that this knowledge base is fundamental to ensuring water quality.

I acknowledge that this is not the sole responsibility of Sydney Water nor the Sydney Catchment Authority. The EPA, NSW Health and the Department of Land and Water Conservation must contribute to the process. Collaboration is required at the relevant level with other industry providers to avoid duplication and ensure the most effective use of research monies.

Appendices

A. Chapter lists from reports 1,2,3 and 4

First interim report - Possible causes of contamination

Executive summary
The water supply system
Cryptosporidium and Giardia in drinking water
What are the bugs?
Are there standards for Cryptosporidium and Giardia levels in drinking water?
What are the consequences of Cryptosporidium and Giardia?
What were the health effects of this incident?
How is drinking water treated?
How are Cryptosporidium and Giardia detected?
Summary of events
Inquiry process
Possible causes of the contamination
Possible Cause 1:
A localised contamination event in the Eastern CBD
Possible Cause 2:
Contamination at Potts Hill reservoir
Possible Cause 3:
Catchment area impacts on the inflow to the Prospect plant
Possible Cause 4:
Contamination at the Prospect plant
Possible Clause 5:
Potential impacts downstream from the Prospect plant
Attachment A
Diagram of water supply system after Prospect plant
Attachment B
Diagram of water supply system before Prospect plant
Attachment C
Map of Prospect plant and surrounds

Second interim report

Management of the events

Executive summary
Introduction
Background
The Warragamba water supply system
Role of Sydney Water

Account of events

Some conclusions

Future directions

Update on cause

Appendices

Third interim report

Assessment of the contamination events and future directions for the management of the catchment

1. Executive summary

2. Cryptosporidium and Giardia A picture of uncertainty

3. Sydney's water treatment plants

Prospect prototype plant
Conclusions

4. Health impacts
Can Cryptosporidium and Giardia make you sick?
Health risks posed by Cryptosporidium and Giardia
What do we know about the health effects of the recent contamination episode?
Future research

5. Sydney's catchments and current management arrangements
Which catchments provide Sydney's drinking water?
How is the Inner Catchment managed and regulated?
How is the Outer Catchment managed and regulated?

6. Possible sources of contamination
What are the possible sources of contamination in the catchment?
Which of these sources pose the highest risk in the catchment?
Conclusions

7. Catchment management regulations and structures
Healthy Rivers Commission Inquiry
Previous reviews of water management
Weaknesses in the management of Sydney's catchment
Recent Government initiatives
What needs to be done to ensure the health of the catchment?
List of references cited

Appendices
Map A Major water filtration plants Sydney water supply system
Map B Sydney's water supply catchments Warragamba and Upper Nepean
Map C Tenure Details in the Inner Catchments
Map D Possible sources of contamination in Sydney's water supply catchments

Fourth report

The contract

1. Executive Summary

2. Introduction

Part I: The process leading to the establishment of the Prospect Water Filtration Plant.

3. The quality of Sydney's water supply before the Prospect Water Filtration Plant
The significance of Prospect to Sydney's water supply
Tell-tale signs of stress
Australian water quality guidelines
What was known of Cryptosporidium and Giardia?
Drinking water program

4. A water filtration plant at Prospect
Resistance to water filtration plants

5. Concept design report and the prototype plant
Water treatment options
Treated water quality goals
Cryptosporidium and Giardia
Prospect prototype research plant

6. To BOOT or not to BOOT private sector participation?
What is a BOOT contract?
BOOT and the Water Board
From BOOT to BOO

7. Expressions of Interest for the water filtration plants
The call for Expressions of Interest
EOI evaluation process stage 1
Result of stage 1

8. Probity audit of stage 1 of the EOI evaluation process
Concerns about the evaluation process
Audit findings
Water Board's response to the audit

9. Selection of pre-qualified tenderers
EOI evaluation process stage 2
Evaluation Committee recommends the pre-qualified tenderers

10. The packaging decision and approval of the pre-qualified tenderers
The packaging concept
BOOT Review Team recommendations
Pre-qualified tenderers approved
Prospect or nothing
Impact of the decision

11. Assessment of tenders
The call for tenders
The evaluation process
Technical assessment
On thin ice AWS' guarantee
AWS makes the grade

B: List of people interviewed from Sydney Water (past/present employees, Board members)

Title	Surname	First Name
Dr	Ashbolt	Nicholas
Mr	Baragry	Craig

Mr	Baxter	Steve
Mr	Broad	Paul
Mr	Butler	Arthur
Ms	Cairnes	Lorraine
Mr	Cork	Ray
Mr	Deen	Amir
Mr	Dodds	Alan
Dr	Fagan	Peter
Mr	Forward	Paul
Ms	Goyal	Raj
Mr	Hart	Warren
Mr	Hawkins	Stephen
Mr	Hill	David
Dr	Hutton	Primrose
Ms	Jones	Amanda
Mr	Johnson	William
Mr	Kay	Stephen
Mr	Keelan	Michael
Dr	Kelly	Bronwyn
Ms	Kibble	Gabrielle
Mr	Mackender	Richard
Mr	Manzi	David
Mr	McCarthy	Jeff
Mr	McMurtrie	John
Dr	Messer	Judy
Mr	Metcalfe	Rod
Mr	Morris	Geoff
Mr	Nicholson	Colin
Mr	Pollett	Chris
Mr	Quill	Ron
Mr	Ridley	Colin
Mr	Roddy	Steve
Mr	Sclater	Keith
Mr	Trickett	Graham
Ms	Tsoukatos	Angela
Mr	Walker	Alex
Dr	Webster	John
Mr	Whitehouse	John
Mr	Withford	Jack
Dr	Wilcox	David
Mr	Wilson	Bob

Dr	Woodward	Ross
Mr	Wright	Tony

C: List of people interviewed

Mr	Alla	Pierre	Australian Water Services Pty Ltd
Mr	Angel	Jeff	Total Environment Centre
Mr	Archer	John	Water Consumers of Australia
Ms	Armistead	Shari	NSW Health
Mr	Bagely	Bruce	Licence Regulator Sydney Water
Cl	Bott	William	Shires Association of NSW
Mr	Browning	Richard	Browning Water Technology
Mr	Callan	Phil	Office of National Health and Medical Research Council
Mr	Canning	Paul	People Living with HIV/AIDS
Dr	Casemore	David	Public Health Laboratory Service, UK
Dr	Chappell	Cynthia	University of Texas (Houston), USA
Dr	Clancy	Jennifer	Clancy Environmental Consultants Inc, USA
Mr	Cleary	Des	Department of Land and Water Conservation
The Hon	Cohen	Ian	Member of the Legislative Council
Mr	Collins	Joe	Treasury
Mr	Connor	John	Nature Conservation Council
Mr	Cook	Michael	Water Flow Control P/L
Ms	Corbyn	Lisa	Environment Protection Authority
Mr	Craig	Keith	formerly of Hunter Water
Dr	Crawford	Peter	Healthy Rivers Commission
Ms	Crawshaw	Karen	NSW Health
Dr	Cunliffe	David	South Australian Health Commission
Mr	Davey	Peter	Hawkesbury-Nepean Catchment Management Trust
Mr	Davis	Chris	Australian Water and Wastewater Assn Inc
Ms	Dixon	Susan	Department of Fair Trading
Mr	Drake	Robert	Department of Fair Trading
Mr	Evans	David	Hunter Water Corporation
Mr	Farmer	Andrew	
Mr	Farrant	Adrian	NSW Health
Ms	Frew	Deborah	NSW Health
Dr	Frost	Floyd	South West Centre for Managed Care Research, USA
Mr	Garling	Philip	Lend Lease Capitol Services Pty Ltd.
Mr	Gifford	Peter	Independent Commission Against Corruption
Mr	Gilmore	John	National Association of Testing Authorities

Mr	Gould	John	Shoalhaven City Council
Mr	Hartnett	Brendan	Local Government and Shires Associations of NSW
Dr	Hawkins	Peter	Australian Water Technologies
Mr	Ho	Michael	Department of Land and Water Conservation
Ms	Holliday	Sue	Department of Urban Affairs and Planning
Mr	Hubbs	Stephen	Louisville Water, USA
Ms	Johnson	Ros	NSW Health
Mr	Junor	Robert	Natural Resources Management Specialist
Mr	Kercher	Bruce	Licence Regulator Sydney Water
Mr	Klem	John	Hawkesbury-Nepean Catchment Management Trust
Ms	Korn	Shelley	People Living With HIV/AIDS
Mr	Koster	Byron	The Cabinet Office
Mr	Laginestra	Mitchell	Water and Wastewater Association Inc
Dr	Langford	John	Water Services Association of Australia
Mr	Longes	Richard	Australian Water Services Pty Ltd
Dr	Macdonald	Peter	Member of Parliament
Dr	MacKenzie	Bill	Centers for Disease Control and Prevention, USA
Ms	McAloon	Jane	Department of Land and Water Conservation
Dr	McAnulty	Jeremy	NSW Health
Mr	McClean	Greg	Lend Lease Infrastructure Pty Ltd
Mr	McLaughlan	Alan	Licence Regulator Sydney Water
Prof	Millis	Nancy	Microbiology School, Univ of Melbourne
Mr	Muir	Keith	Colong Foundation
Mr	Murray	Bruce	City Water Technology Pty Ltd
Mr	Musgrave	Warren	Premier's Department
Mr	O'Donoughue	Ross	NSW Health
Ms	Orlova	Tanya	National Association of Testing Authorities
Prof	Parry	Tom	Independent Pricing and Regulatory Tribunal
Mr	Pidcock	Denis	formerly of NSW Treasury Corporation
Mr	Prineas	Peter	Licence Regulator Sydney Water
Mr	Rayner	Mike	Tweed Shire Council and Chairperson, Interim Water Directorate
Mr	Reid	Mick	NSW Health
Mr	Rhodes	Doug	Department of Land and Water Conservation
Ms	Robertson	Jane	Licence Regulator Sydney Water
Mr	Ross	Tony	Upper Nepean Catchment Management Committee
Mr	Rouse	Michael	Drinking Water Inspectorate, UK
Mr	Rowe	Malcolm	Local Government and Shires Associations of NSW
Mr	Russell	John	Department of Land and Water Conservation
Mr	Russell	Anthony	National Association of Testing Authorities
Dr	Schaefer	Frank	Environmental Protection Agency, USA

Dr	Shepherd	Neil	Environment Protection Authority
Mr	Smalls	Ian	Centre for Natural Resources, Land and Water Conservation
Dr	Smith	Robert	Department of Land and Water Conservation
Dr	Smithyman	Anthony	Cellabs Pty Ltd
Mr	Speed	Hugh	AWS/Lyonnaise
Ms	Thompson	Nivek	Department of Fair Trading
Prof	Tzipori	Saul	Tufts University, USA
Mr	Verhey	Bob	Local Government and Shires Associations of NSW
Mr	Weir	Bryan	formerly of Freehill Hollingdale & Page
Dr	Wilson	Andrew	NSW Health
Cl	Woods	Peter	Local Government Association of NSW
Mr	Woodward	Joe	Environment Protection Authority

D: List of submissions received

Submissions relating to terms of reference

Allen J
Ashton D
Australian Services Union of New South Wales
Barsoum L
Beach R
Beard J
Bennett R
Bignoculo J
Black K
Blewett G
Bodycomb A
Brady K
Bricknell J R
Broad J
Burke P
Buttiglieri R
Carlos B
Carlysle-Sainty R & P
Cattle Out of Water
Caville R N
Chand K
Chevis R
Chikarovski MP K
City Water Technology
Clark D
Clark J & P
Clean Water Coalition
Colong Foundation for Wilderness
Cooper R B
Corcoran B
Coren M
Council of Social Services of NSW

Council of Sutherland Shire
Coxs River Catchment Committee
Cullan J
Cullen J
Davies D I
Davies G
Davis G
Department of Fair Trading
Diestal D
Donnellan T
Drexel University Philidelphia
Dulwich Hill Preschool
Environment Management Industry Association of Australia Ltd
Etherden S E
Ethnic Affairs Commission
Feehan J
Feehan J
Felder C
Fernando A
Findlay C
Fitzgerald P
Ford B
Fowler M
Friends of the Earth
Graceades Community Cottage Inc
Hanley D
Hawkesbury Nepean Catchment Management Trust
Hessey P
Hi Tech Marine International Pty Ltd
Hogan L J
Hudson S
Hunters Hill Council
Hyde D
Ireland & D Chapman M
Irvine EFL
J Hogan D
Jewson B
Johnson B
Junor R S
Kenny R
King J
Kingfisher Centre
Korn S
Kyeho Y I
Lambe P
Lee A
Lucas EL
M McLeod E
Master Plumbers & Mechanical Contractors Association of NSW
Maurer C
Mayman P
McLaren N
Medical Consumers Association (NSW)
Mitchell M
Mitnovetsky R
Moore G
Moore MP C
Mouritz M
Naidoo T
Noad B

Noon M
Northern Sydney Regional Organisation of Councils
Pearce F
Perry P
Plan of Management Advisory Group
Preston B
Public Interest Advocacy Centre
Roach B
Robbins A
Ruser B & K
Schofield P
Schofields M. Cycles
Scragg W & EE
Shaw R
Short F
Sinfield R
Smith B
Smith L
Sri Lanka Arts Council of Australia Inc
Stephens G
Supaflo Technologies Pty Ltd
Sydney Fly Rodders Club
Talbot R
Taylor K K
Tenants' Union of NSW
The Oaks Clean Our Gutters Group
Tranter D
Trubridge-Freebury J
Upper Nepean Catchment Management Committee
Urban J
Wight G
Wilson M
Wilton J
Wimhurst R
Wingecarribe Shire Council
Wiseham M
Wollondilly Catchment Management Committee
Wood G S
Youndale G
Young R

Hogan J D
Hunters Hill Council
Hyde D
Ireland & D Chapman M
Irvine EFL
Jewson B
Johnson B
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Wight G
Wilson M
Wilton J
Wimhurst R
Wingecarribe Shire Council
Wiseham M
Wollondilly Catchment Management Committee
Wood G S
Youndale G

Young R

Submissions offering products

Aguapro Australia Pty Ltd
American Water Works Service Company Inc
Amicross Environmental Pty Ltd
APS Ajax Specialtychem
ASP Plastics

Associates Network
Aus-Sea Pty Ltd
Australian Water & Wastewater Association Inc
Baldwin Industrial Systems
Besafe Industries Pty Ltd
BJP Management Consultants
Bureau Veritas
CDS Technologies
CeLLabs Pty Ltd
Cheltec Incorporated
Conrex Pty Ltd
Culligan Australia Pty Ltd
Donovan Pty Ltd
Drury S
Emblem Crest Pty Ltd
Enviro-Water Pty Ltd
Exponent
Filchem Australia Pty Ltd
Fog Eliminator
Frequency Management Adelaide
Gemmert P Van
Global Marketing Development Corporation
Grander Water Technologies (Australia) Pty Ltd
Guard Management Systems
Gunderboom Inc
Heavy Metal Resource Recovery Pty Ltd
International Ozone Association
Isotrol (Australia) International Pty Ltd
LWK Engineering Pty Ltd
MCV Australia Pty Ltd
Morison & Morison Pty Ltd
Morison M C
Northern Medical Research Foundation
Pacific Dynamics
Partnership for Safe Water
Pneumatic Systems International Pty Ltd
Reconditioned Water
Recover Pty Ltd
Research Directions
Systematics
Triangle Filtration
TZF Technologies
USF Filtration Limited
Wade A
Watermaster Technologies Ltd
Welch C
Witford J
Worldwide Environmental Solutions Pty Ltd
Zeolite Australia Ltd

E: Issues raised in public submissions

The following points summarise matters raised by individuals and groups who made submissions to the Inquiry. Many of the points are the subject of discussion and findings in the various chapters of this report.

Health concerns

- Illness has been caused by the water contamination.
- The presence of Cryptosporidium in the water is an important issue to people in NSW who are immuno-compromised. What certainty can be given that the quality of the water is drinkable, particularly for immuno-compromised people? There are also other parasites that are of concern, including Microsporidia, Entamoeba histolytica, Naegleria fowleri and Cyclospora cayetanesis.
- Sydney Water and NSW Health have not advised immuno-compromised people to boil water during the past few years. Public information about the risks to immuno-compromised people has been confusing, inconsistent and misleading.
- Hospitals must ensure that the water is constantly and consistently filtered.
- Chlorine might be a danger to the unborn.
- The level of chlorination prior to and after the incident and whether it has been tested is queried.
- NSW Health and Sydney Water are not giving to the public information about the effects of Cryptosporidium and Giardia.
- There are identifiable diseases among the population of Sydney as a result of the Sydney water contamination.
- Various submissions highlight illness caused by the contamination for example giardiasis, stomach cramps, diarrhoea, severe skin problems, chest infections and headaches.
- The health of the population of Sydney has been compromised because Sydney Water rejected a dual filtration tender for the Prospect plant.
- Surveillance methods utilised by NSW Health were not capable of detecting increased disease.
- No action was taken when a number of individuals advised Sydney Water they were suffering from acute gastrointestinal problems and suspected that the water was contaminated in mid July. Sydney Water tested the water but not for Cryptosporidium and Giardia and people were advised that the quality was within the guideline parameters. Following 1 August, Sydney Water was again contacted. Advice given was that since the illness suffered was prior to this date the matter was not relevant.

Compensation

- What guarantee will the Government provide to ensure that users renting properties receive compensation payments rather than landlords?
- Should the Residential Tenancies Tribunal make an order that owners of properties must compensate people who are renting properties for the additional electricity costs in boiling water and purchasing bottled water?
- There is a concern that Sydney Water accounts should not be paid until water quality issues are resolved.
- The Minister should be asked to cancel any increases in water service or supply charges until the Sydney water supply issues are resolved.
- The crisis will have an impact on low-income earners' access to rebates.
- People who have on the advice of NSW Health "held down the button on automatic kettles for a full minute" should be compensated if those kettles broke.

Catchment management

- Animals have died around the Warragamba Dam catchment as a result of fires, starvation and drought. Should controlled culling of wildlife be undertaken?
- Is the faecal matter from animals contributing to the parasites in Lake Burragorang?
- There may be ideological differences on catchment management between the National Parks and Wildlife Service and Sydney Water?
- A feasibility study should be undertaken in areas where "untreated sewage" is entering the river systems eg. Goulburn, Bowral, Mittagong and Bundanoon.
- Ongoing sampling in the Outer Catchment would have identified the presence of any number of pollutants.
- Surveillance and maintenance personnel were removed from monitoring the canals and pipelines.
- There are insufficient personnel to protect the catchment.
- Lithgow and other areas of the catchment could be contributing to the contamination of Sydney water.
- Miners and farmers or vandals and terrorists could put anything into Sydney water.
- People who have been paying levies to clean up the local river systems want to know why the levies are still required.
- Sydney Water has deliberately reduced the level of park rangers patrolling the catchment, and the technical personnel maintaining scientific surveillance of the water supply.
- Government has failed to prevent further settlement in the catchment.

- Water levels in the dam are significantly down prior to La Nina rains in winter this year.
- Current and successive governments have failed to effectively manage the catchment and conduct effective urban management.
- Wingecarribee Swamp collapsed and released contaminated water into the reservoir, perhaps contributing to the problem.
- Wingecarribee Swamp is drying out and it might catch fire and endanger species.
- A channel from Robertson to the Wingecarribee Swamp is unsewered.
- The Wingecarribee Swamp should be rehabilitated.
- The Catchment Commission should also focus on the Inner Catchment.

Management of the incident

- Sydney Water provided inconsistent information.
- There was insufficient notification to customers on the extent of the problem prior to the incident.
- Sydney Water did not adequately communicate with people of non-English speaking backgrounds until two days into the incident, following a media article.
- The final advertisement that Sydney Water issued recommended that people pass on the information to friends and neighbours who do not speak English. There was no telephone number for these people to receive the latest information.
- SBS was seen as the agent to get the message across to the ethnic communities. There are a number of ethnic media daily programs (radio and newspapers) that can reach the communities.
- It took Sydney Water and NSW Health five days to disclose and publicise the contamination.
- A boil water alert for all of Sydney should have been announced.
- Sydney Water and NSW Health are giving conflicting messages to immuno-compromised individuals.
- International experts are being used to solve the water contamination issue, although the treatment plant has been designed using overseas technology.

Corporatisation

- Dramatic cutbacks were made to the Water Quality Sampling Program in the river systems upstream of the storage.
- Since the corporatisation of Sydney Water a reduction in personnel has caused a number of problems, including occupational health and safety issues.
- Since corporatisation, personnel at SWC have been reduced, water prices have increased along with dividends paid to the Government. The Government has used the dividend for other policy objectives, resulting in the water contamination.
- Sydney Water does not have the appropriate personnel to manage and work in the organisation.
- Sydney Water has failed to adopt ozonation despite AWS' recommendation to do so.
- Is there conflict between corporate structures, profit margins, service delivery and customer service within Sydney Water?
- The effect of corporatising and privatising public utilities reduces the transparency and accountability of senior management to the Government and community.

Sydney water quality

- What assurance can be given that the quality of the water is acceptable to drink?
- Sydney is being seen as a third world country because of the quality of the drinking water.
- Sydney Water did not make it mandatory that a particulate counter be installed to monitor the water.
- What is the source of the contamination?
- What action is being undertaken to prevent recurrence of the contamination?
- Cryptosporidosis and giardiasis might be prevalent in the Avalon area.
- Cryptosporidium and Giardia has been in the water for years.
- There should be system checks and regular reviews and audits of water quality.
- Sludge and sewage waste is not being adequately heat sterilised to kill pathogens.
- People should not be drinking recycled sewage water, even though, technically it is potable.
- The proposed location and design of the Western Sydney Orbital Road should not take place until people are warned about various dangers, including the Upper Drinking Water Canal.
- The Inquiry's Terms of Reference do not investigate pollution as a cause of water quality problems, or the ecological and human health risks of chemicals in sewage treatment plants.
- Water travelling from Warragamba dam to the Prospect plant does not meet the health-related parameters of the NHRMC.

Water filtration and monitoring

- The Prospect plant was not contracted to detect Cryptosporidium and Giardia.
- If there are thousands of chemicals added to Sydney water, why are only ten tested?
- Traditional testing can take between four days and two weeks for results and people could be drinking and/or swimming in the water before the tests are known.
- The NHMRC Australian Drinking Water Guidelines 1996 do not require routine monitoring for Cryptosporidium and Giardia.
- In the Merriwa area people are concerned that they have been experiencing third world water and sanitary conditions.

Future directions

- Does the Government have a plan to solve the problem?
- The Premier should guarantee that the incident will not happen again.
- The Board of Sydney Water should represent and be accountable to all stakeholders.
- What plans are there to ensure that there will not be any issues regarding the quality of drinking water during the Sydney 2000 Olympic Games?
- The Premier and the Board of Sydney Water should accept responsibility for the management of Sydney water.
- A communications strategy should be developed which includes media outlets used by ethnic communities, including early contact with the Ethnic Affairs Commission.
- There needs to be clear policy on water quality safety for immuno-compromised members of the community.
- People who are immuno-compromised may need financial support eg. rebates or subsidies. Alternatively, they could be provided with bottled water or purifiers.
- Regulations should be developed to standardise the safety of bottled water and guidelines provided on the removal of microorganisms eg. Cryptosporidium and Giardia.
- Standardised labels for bottled, dispensed water products and filters should be required to show if they meet standards for removing parasites. Warnings and information about the safety of changing the filters should be available.
- Regulatory guidelines should be developed by hospitals, companies and other institutions producing bottled or dispensed water.
- Water is a valuable resource and Sydney Water could charge more for it to reduce people actually wasting water.
- People should be encouraged to have rain water tanks on their properties, including metropolitan dwellings.
- A code of ethics should be developed for Sydney Water with the mission that it supplies safe and adequate water.
- Amend c 11 (1) (b) of the Residential Tenancies Regulation 1995 to allow tenants who pay the "water usage charge" to receive a "service disruption rebate". Presently, it is only the landlord who pays the "water availability charge" who will benefit from the rebate. Rebates should be lodged via the rental bonds system. Consideration needs to be given to provision of rebates where individual premises are not metered.
- Boarders and lodgers might lack legislative coverage or mechanisms to recover costs.
- A cumulative impact study should be undertaken on the Prospect plant.
- The plant should be upgraded to the cost of approx $200 million.

F: List of advisers

Title	Surname	First Name	Position	Organisation
Dr	Ashbolt	Nicholas	Associate Professor	Dept of Water Engineering, University of NSW

Mr	Bayley	Robin	Principal Scientist	Thames Water Utilities Ltd, UK
Dr	Brignal	William	Process Specialist	Thames Water Asia/Pacific
Dr	Chalmers	John	Chairman of Research	Royal North Shore Hospital
Dr	Chipps	Michael	Principal Research	Thames Water Utilities Scientist, Research Ltd, UK and Technology
Assoc Prof	Fairley	Christopher	Deputy Program Coordinator Health Risk Assessment CRC for Water Quality and Treatment	Dept of Epidemiology & Preventive Medicine Alfred Hospital
Dr	Fricker	Colin	Microbiology and Laboratory Manager	Thames Water Utilities Ltd, UK
Mr	Harley	David	Chairman	NSW Environment Protection Authority
Dr	Harris	Graham	Chief of Land and Water	CSIRO
Mr	Holmes	Michael	Research Scientist/Engineer	Thames Water Utilities Ltd, UK
Dr	Hooper	Bruce	Snr Research Fellow, and Director, Environmental Unit Planning Research	Dept of Geographical Sciences and Planning, The University of Queensland
Prof	Imberger	Jorg	Professor of Environmental Engineering, Director of the Centre for Environmental Fluid Dynamics and Chair of the Centre for Water Research	The University of Western Australia
Mr	McKay	Bernie	Managing Director	Bernie McKay & Assoc.
Prof	McNeil	John	Professor	Dept of Epidemiology and Preventive Medicine, Monash University
Dr	O'Donoghue	Peter	Senior Lecturer	Dept of Parasitology, The University of Queensland
Dr	Ongerth	Jerry	Visiting Professor	Dept of Water Engineering, School of Civil Engineering, University of NSW
Dr	Veal	Duncan	Snr Lecturer in Biology	School of Biological Sciences, Macquarie University
Dr	Walker	John	Director	Dept of Parasitology, Centre for Infectious Diseases and Microbiology, University of Sydney Westmead Hospital

Witness / interested party	**Legal advisers**
Sydney Water	Mr T E F Hughes QC Mr T Bathurst QC

	Mr S Clark (Clayton Utz) Mr P Silver (Clayton Utz) Ms K O'Flynn (Clayton Utz) Mr C Loveday (Clayton Utz)
Australian Water Services	Mr R Gyles QC Mr K Broadley (Freehill Hollingdale & Page) Ms C Murphy (Freehill Hollingdale & Page)
Australian Water Technologies	Dr A Bennett SC Mr B O'Connell (Australian Water Technologies)
Dr Peter Fagan	Dr A Bennett SC Mr B O'Connell (Australian Water Technologies)
Mr Paul Forward	Mr G Kent (Blake Dawson Waldron)
Mr David Hill	Mr B Rayment QC Mr G Downes QC Mr J Simpkins Mr J Wotton (Phillips Fox) Mr S Reilly (Phillips Fox)
Dr Bronwyn Kelly	Dr A Bennett SC Mr B O'Connell
Mr David Manzi	Mr P Silver (Clayton Utz) Ms K O'Flynn (Clayton Utz)
Mr Ron Quill	Mr P Silver (Clayton Utz)
Mr John Shirbin	Mr RJ Ellicott QC Ms K O'Flynn (Clayton Utz)
Mr Graham Trickett	Mr S Clark (Clayton Utz) Mr P Silver (Clayton Utz)
Mr Jack Withford	Mr P Silver (Clayton Utz)

H: Joint Action Group (JAG) members

Dr Bellamy	Bill	Director, Water Treatment	CH2M Hill
Mr Deen	Amir	Hydrology Manager	Sydney Water
Mr Gaston	John	Senior Consultant, Water Quality and Regulations	CH2M Hill
Mr Giggacher	Manfred	Project Manager	Australian Water Services
Mr Henderson	Greg	Project Director	Suez Lyonnaise des Eaux
Mr Kane	Greg	Manager, Network Operations	Sydney Water

Mr	Mazounie	Pierre	Assistant to the Director	Suez Lyonnaise des Eaux
Mr	McClean	Greg	Project Manager	Lend Lease
Mr	Nicholson	Colin	Manager, Operations Services	Sydney Water
Ms	Patania	Nancy	Principal Engineer	Montgomery Watson
Mr	Roddy	Steve	Senior Consultant	Australian Water Technologies
Mr	Williamson	Mike	Managing Director (Australia)	CH2M Hill
Mr	Wills	David	Project Manager	CH2M Hill

I: Table of positive Cryptosporidium and Giardia counts

Sydney Water Contamination Incident – 21/7/98 to 19/9/98

Date	Sampling Site Description	Crypto Count	Crypto adjusted (Number/100L)	Giardia Count	Giardia adjusted (Number/100L)
21-Jul-98	Sydney Hospital, Hospital Road	ND	0	1	1
22-Jul-98	Sydney Hospital, Hospital Road	48	48	19	19
23-Jul-98	Sydney Hospital, Hospital Road	ND	0	1	1
23-Jul-98	[illegible] North Building Sydney Hospital	1	1	ND	0
[illegible]	Art Gallery Road, Sydney	[illegible]	19	[illegible]	[illegible]
[illegible]	Macquarie St, Sydney - Hospital	12	13	[illegible]	[illegible]
[illegible]	Art Gallery Road, Sydney	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Crown Street Pumping Station	[illegible]	[illegible]	5	5
[illegible]	Cnr Liverpool & Crown Street	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	College St, Sydney - Museum	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Macquarie St, Sydney - Hospital	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	College St, Sydney - Museum	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Art Gallery Road, Sydney	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Crown Street Reservoir - Depth	[illegible]	6	[illegible]	[illegible]
[illegible]	Cnr Liverpool & Crown Sts	1	1	[illegible]	[illegible]
[illegible]	Main City Tunnel	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	College St, Sydney - Museum	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Crown Street Reservoir - Depth	ND	[illegible]	14	14
[illegible]	Llewellyn St, Rhodes	ND	0	4	4
[illegible]	Macquarie St, Sydney - Hospital	[illegible]	[illegible]	1	1
[illegible]	Macquarie St, Sydney - Hospital	1	1	ND	0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Main City Tunnel	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Llewellyn St, Rhodes	1	1	1	1
[illegible]	Potts Hill Reservoir Suction Well	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	College St, Sydney - Museum	[illegible]	2	ND	0
[illegible]	Art Gallery Road, Sydney	[illegible]	4	ND	0
[illegible]	Centennial Park Reservoir No.1	[illegible]	7	1	1
[illegible]	Crown Street Reservoir - Depth	1	1	1	1
[illegible]	Potts Hill Reservoir No. 1 Site [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Potts Hill Reservoir No. 1 Site [illegible]	[illegible]	[illegible]	ND	0
[illegible]	Potts Hill Reservoir No. 1 Site 1 centre of reservoir	10	[illegible]	[illegible]	[illegible]

Date	Sampling Site Description	Crypto Count	Crypto adjusted ([illegible])	Giardia count	Giardia adjusted ([illegible])
29-Jul-98	Cnr Liverpool & [illegible] Place	21	21	5	3
29-Jul-98	59 Llewellyn St, Rhodes	[illegible]/L	290	785/L	47
29-Jul-98	Potts Hill Reservoir Suction Well	272	272	109	109
29-Jul-98	Schofields Rd, Rouse Hill	11650/L	620	30450/L	9
29-Jul-98	Boundary Rd, Oakville	698	208	184	184
29-Jul-98	Prospect WFP Clear Water Tanks	165	165	236	236
29-Jul-98	Main City Tunnel	901	901	333	333
29-Jul-98	[illegible] Rd, Granville	2541/L	1524	8751/L	33
29-Jul-98	Crown Street Reservoir - emptying ([illegible])	30	36	24	24
29-Jul-98	Macquarie St, Sydney - Hospital	425	425	202	202
29-Jul-98	Prospect WFP Clear Water Tanks	2	2	1	1
29-Jul-98	College St, Sydney - Museum	2150	2150	249	249
[illegible]	Crown Street Reservoir - first half batch sample	120	120	ND	0
[illegible]	64 Bettington Ave, Oakville	[illegible]/L	39	10430/L	0
[illegible]	Prospect WFP Backwash - Filter 1/2	1*	1	[illegible]*	0
[illegible]	Prospect WFP Lagoon No. [illegible]	[illegible]/L	0	[illegible]/L	49
[illegible]	Wilson Road, [illegible] Heights - Hydrant [illegible]	4	0	ND	0
[illegible]	Schofields—Near Railway Terrace Hydrant No. [illegible]	20	20	4	5
[illegible]	Thornleigh Reservoir	4	0	ND	0
[illegible]	Potts Hill Inlet to Pressure Tunnel at No. 1 Reservoir	[illegible]/L	993	[illegible]/L	857
[illegible]	Illawarra WFP Finished Water [illegible]	52	52	2	2
[illegible]	Prospect WFP R/S Distribution Chamber Outlet	625	325	75	29
[illegible]	Inlet to Potts Hill Shaft (pipe 3)	98	98	23	23
[illegible]	Potts Hill Pipe 3 — [illegible]	99	99	32	32
[illegible]	Station Street, Botany	52	52	3	3
30-Jul-98	Brooklyn Rd, Brooklyn - near [illegible]	[illegible]/L	580	[illegible]/L	3
30-Jul-98	Cnr [illegible] & [illegible] Palm Beach - Hydrant	365	365	151	156
30-Jul-98	Warragamba Pipeline No. 1 @ Henley Rd	429	429	79	79
30-Jul-98	Campbelltown [illegible] Reservoir [illegible]	1	1	2	2
30-Jul-98	Pressure Tunnel Shaft 6 Enfield Depot	12	12	499	0
31-Jul-98	Prospect WFP Filter Module 1	[illegible]/L	2	[illegible]/L	0
31-Jul-98	Warragamba Pipeline No. 2 @ Henley Rd	[illegible]	9	[illegible]/L	2
31-Jul-98	Prospect WFP Post Filter [illegible] - Composite	36	6	1	1
31-Jul-98	Warragamba Pipeline No. 1 @ Henley Rd	[illegible]/L	443	[illegible]/L	5
31-Jul-98	Centennial Park Reservoir No. 1	2	2	1	1

Date	Sampling Site Description	Crypto Count	Crypto adjusted (Number/100L)	Giardia Count	Giardia adjusted (Number/100L)
30-Jul-98	Potts Hill Inlet to Pressure Tunnel at No. 1 Reservoir	10/20L	500	60/20L	297
30-Jul-98	Prospect WFP Filter Module 3	23/30L	77	ND/30L	0
31-Jul-98	Warragamba Dam - 48m	16/20L	80	5/20L	25
31-Jul-98	Prospect WFP Post Filter Weir - Composite	8/100L	8	8/100L	8
01-Aug-98	Potts Hill Inlet to Pressure Tunnel at No. 1 Reservoir	127	127	ND	0
01-Aug-98	Broughton Pass Weir	ND	4	1	1
02-Aug-98	Prospect WFP Inlet to Contact Channel south	7^	7	ND^	0
02-Aug-98	[illegible] Reservoir	1	1	ND	0
03-Aug-98	Illawarra WFP Raw Water	2/50L^	4	ND/50L^	0
04-Aug-98	Prospect WFP Raw Water - Lab tap post chl	4/20L	5	4/20L	0
04-Aug-98	Prospect WFP Supernatant Return	5/2L^	250	ND/2L^	0
04-Aug-98	Prospect WFP Raw Water - Lab tap post chl	4/30L	6	4/30L	0
05-Aug-98	Cordeaux Dam - 15m	4/30L^	13	ND/30L^	0
05-Aug-98	Woronora Dam - 18m	4/50L^	8	4/40L^	10
05-Aug-98	Prospect WFP Clear Water Tank No. 2 - East 3	3^	3	4^	5
05-Aug-98	Prospect WFP Clear Water Tank No. 2 - West 1	2^	2	ND^	0
05-Aug-98	Prospect WFP Clear Water Tank No. 2 - West 3	ND^	0	2^	2
05-Aug-98	Prospect WFP Clear Water Tank No. 2 - East 1	4^	4	1^	1
05-Aug-98	Warragamba Dam - top 5m	1/50L	2	ND/20L	0
05-Aug-98	Spillway from the Prospect Reservoir	ND/70L^	0	1/72L^	1
05-Aug-98	Upper Canal at Sugarloaf	ND^	0	24^	24
05-Aug-98	Wollondilly River @ Jooriland	ND/80L^	0	1/15L^	7
05-Aug-98	Warragamba Dam - bottom 5m	2/10L^	20	ND/10L^	0
05-Aug-98	Warragamba Dam - 7m	1/25L	4	1/25L	4
05-Aug-98	Prospect Reservoir	ND/25L^	0	1/25L^	4
06-Aug-98	Prospect WFP DE-Distribution Chamber Outlet	1	1	ND	0
06-Aug-98	Broughton Pass Weir	1/20L^	5	ND/20L^	0
06-Aug-98	Woronora WFP Raw Water	1/30L^	3	ND/30L^	0
06-Aug-98	Wingecarribee Reservoir - Bulkhead Pool	5/2L	250	ND/2L	0
06-Aug-98	Warragamba Dam - 5m	2/30L^	7	ND/30L^	0
10-Aug-98	Cascade Creek WFP Raw Water	5/25L^	20	ND/25L^	0
11-Aug-98	North Richmond WFP Raw Water	1/3L^	33	ND/3L^	0
13-Aug-98	Wentworth Creek	1/25L^	4	1/25L^	4
13-Aug-98	Prospect WFP Post Filter Weir - Composite	2	2	1	1
13-Aug-98	Prospect WFP Inlet to Contact Channel	4/25L	16	10/25L	40

Date	*Sampling Site Description*	*Crypto Count*	*Crypto adjusted (Number/100L)*	*Giardia Count*	*Giardia adjusted (Number/100L)*
12-Aug-98	Prospect Reservoir Southern Outlet Works – bach...	12	12	5	5
13-Aug-98	Main City Tunnel	9	9	0	0
13-Aug-98	Warragamba Dam - 45m	20/4L^	709	15/4L^	[illegible]
13-Aug-98	Warragamba Dam - 42m	2/10L^	237	18/2L^	211
13-Aug-98	Warragamba Dam - 14m	4/2L^	3	ND/20L^	0
13-Aug-98	Prospect WFP Supernatant Return	295/10L	2359	27/9L	29
13-Aug-98	Prospect WFP DCS Distribution Chamber Outlet	50	50	22	22
13-Aug-98	Warragamba Dam - 37m	86/4L^	8976	15/7L^	1870
14-Aug-98	Warragamba Dam - 16m	6/20L^	97	ND/20L^	0
14-Aug-98	Orchard Hills WFP Raw Water	5/20L^	14	ND/25L^	0
14-Aug-98	Prospect Reservoir Southern Outlet Works No.3	4/20L^	2	ND/20L^	0
14-Aug-98	Prospect WFP Junction Chamber	22*	97	40	10
14-Aug-98	Prospect WFP Swamp... Junction Chamber	252/10L	2579	180/10L	1020
14-Aug-98	Prospect WFP DCS Distribution Chamber Outlet	15	15	16	16
14-Aug-98	Prospect WFP Backwash	185/10L	1855	ND/10L	0
15-Aug-98	Prospect WFP DCS Distribution Chamber Outlet	ND/20L	0	1/20L	1
18-Aug-98	Farmers Creek St, Lithgow STP	1/5L	20	1/5L	20
20-Aug-98	Macarthur WFP SP4 finished water	5^	5	ND^	0
20-Aug-98	North Richmond WFP Reservoir	1	1	ND	0
20-Aug-98	Prospect WFP Supernatant Return	80/4.2L	2420	57/24L	235
21-Aug-98	Prospect WFP Backwash - Filter 2/3	11/10L	1120	ND/10L	0
21-Aug-98	Main City Tunnel	1	1	ND	0
21-Aug-98	Prospect WFP Inlet to Contact Channel	3/20L^	3	ND/20L^	0
21-Aug-98	Potts Hill Reservoir No. 1 Site (centre of reservoir)	2/12.5L^	6	0/12.5L^	2
21-Aug-98	Wollondilly River @ Scotland	7/5L^	140	1/2L^	20
21-Aug-98	Potts Hill Reservoir No. 1 Site 3 NW corner of reservoir	2^	2	ND^	0
21-Aug-98	Prospect WFP DCS Distribution Chamber Outlet	13	13	9	9
21-Aug-98	Prospect WFP Finished Water	8/12.5L	64	0/12.5L	0
21-Aug-98	Prospect WFP Supernatant Return	40/20L	2007	22/15L	147
21-Aug-98	Prospect WFP Upper Canal Inlet to Channel 2	0/20L	1?0	6/20L	0
21-Aug-98	North Richmond WFP Reservoir (Match on ...)	4/5L	80	ND/5L	0
21-Aug-98	North Richmond WFP Reservoir	1	1	ND	0
22-Aug-98	Prospect WFP Inlet to Contact Channel	1/50L^	2	1/50L^	2
22-Aug-98	Sydney Hospital, Hospital Road	1*	1	ND*	0
22-Aug-98	23 Lennox St, Darlinghurst	1*	1	ND*	0

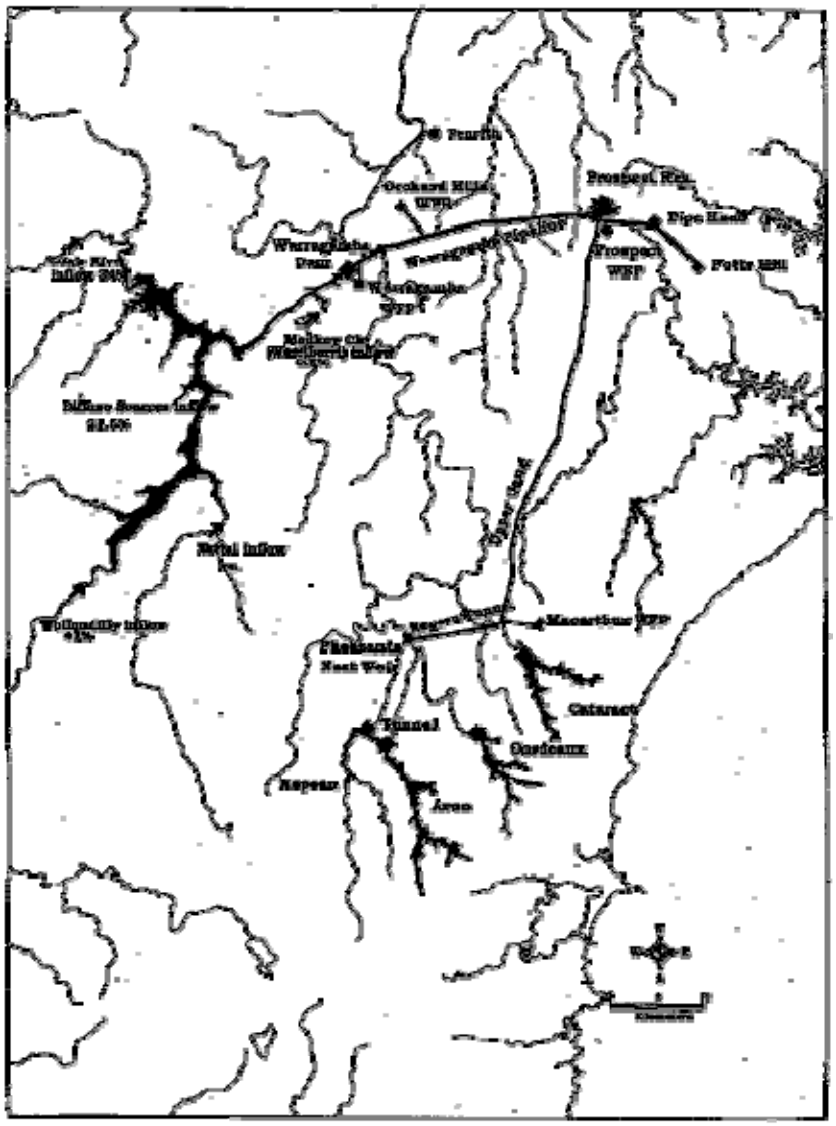
Date	Sampling Site Description	Crypto Count	Crypto adjusted (Chamber/100L)	Giardia Count	Giardia adjusted (Chamber/100L)
24-Aug-98	119 Pacific Rd, Palm Beach	[illegible]	[illegible]	347	347
24-Aug-98	Warragamba Dam - 30m	[illegible]	[illegible]	11/20L	57
24-Aug-98	Nattai River at Mittagong	[illegible]	6	2/10L^A	20
24-Aug-98	Prospect WFP Inlet to Contact Channel	[illegible]	[illegible]	4/20L	20
24-Aug-98	Prospect WFP O/S Distribution Chamber Outlet	73	73	16	16
24-Aug-98	Prospect WFP Finished Water	[illegible]	1920	[illegible]	345
24-Aug-98	Sydney Hospital, Hospital Road	[illegible]	[illegible]	59	59
24-Aug-98	29 Lawson St, Darlinghurst	570	570	22	22
25-Aug-98	Prospect WFP Supernatant Return	ND/40L	0	1/10L	10
25-Aug-98	Sydney Hospital, Hospital Road	5	5	2	2
25-Aug-98	29 Lawson St, Darlinghurst	1	1	ND	0
25-Aug-98	Macquarie St, Sydney - Hospital - No.1 Hydrant	20/20L	100	3/20L	15
25-Aug-98	Prospect WFP Finished Water	21	21	ND	0
25-Aug-98	Prospect WFP Supernatant Return	25/20L	125	1/20L	5
25-Aug-98	Prospect WFP Foam [illegible]	[illegible]	[illegible]	ND/500mL^A	0
26-Aug-98	Prospect WFP Finished Water	20	20	4	4
26-Aug-98	Prospect WFP O/S Distribution Chamber Outlet	140	140	60	60
26-Aug-98	Prospect WFP Finished Water	51	51	18	18
26-Aug-98	Prospect WFP Sub-Junction Chamber	152/10L	1520	42/10L	420
26-Aug-98	Prospect WFP Inlet to Contact Channel	400/25L	1600	81/25L	324
26-Aug-98	Prospect WFP Inlet to Contact Channel	580/10L	5800	193/10L	1930
26-Aug-98	Prospect WFP O/S Distribution Chamber Outlet	1	1	1	1
26-Aug-98	Orchard Hills WFP Reservoir [illegible]	114	114	17	17
26-Aug-98	Prospect WFP O/S Distribution Chamber Outlet	32	32	ND	0
26-Aug-98	Warragamba Dam - 25m	[illegible]	[illegible]	15/25L	60
26-Aug-98	Prospect WFP Supernatant Return	[illegible]	[illegible]	[illegible]	0
26-Aug-98	Warragamba Dam - 16m	74/10L	740	6/10L	60
26-Aug-98	Prospect WFP Clear Water Tanks	4	4	1	1
26-Aug-98	Warragamba Dam - 30m	[illegible]	[illegible]	78/10L	780
26-Aug-98	Prospect WFP Inlet to Contact Channel	[illegible]	[illegible]	ND/20L	0
26-Aug-98	Prospect WFP Inlet to Contact Channel	[illegible]	[illegible]	[illegible]	10
26-Aug-98	Prospect WFP Channel 2.220m U/S	[illegible]	[illegible]	4/25L	16
26-Aug-98	Prospect WFP Inlet to Contact Channel	[illegible]	147	[illegible]	17
26-Aug-98	Prospect WFP Backwash - Filter 4.3	[illegible]	[illegible]	ND/10L	0
27-Aug-98	Prospect WFP Channel 2.220m U/S	[illegible]	[illegible]	[illegible]	[illegible]

Date	Sampling Site Description	Crypto Count	Crypto adjusted (Number/100L)	Giardia Count	Giardia adjusted (Number/100L)
04-Sep-98	Prospect WFP Finished Water	>500	526	>3500	3500
05-Sep-98	East Hills Composite Res[illegible]	1^	1	ND^	0
04-Sep-98	Prospect North - Upper Bur 3 composite [illegible]	328	330	455	455
04-Sep-98	[illegible]	[illegible]	0	[illegible]	80
04-Sep-98	6 Riley Ave, West Pennant Hills	29/20L	180	93/10L	930
04-Sep-98	2 Hart Ave East	5/10L	50	2/10L	20
04-Sep-98	Warragamba WFP Reservoir	121	184	259	259
04-Sep-98	[illegible] Orange Grove, Castle Hill	21/10L	210	62/10L	620
04-Sep-98	Warragamba Dam Pipeline [illegible]	[illegible]	13240	[illegible]	7320
04-Sep-98	Prospect WFP Finished Water	0	0	1	1
04-Sep-98	Macarthur WFP [illegible] filtered water [illegible]	[illegible]	0	1	[illegible]
04-Sep-98	[illegible] Ave, Castle Hill	[illegible]	[illegible]	[illegible]	[illegible]
04-Sep-98	Warragamba WFP Raw Water	[illegible]	570	47/10L	208
04-Sep-98	Cataract Dam [illegible] - Composite	63/5L^	2903	32/5L^	1906
04-Sep-98	Orchard Hills WFP Clear Water Tank	80	19	ND	0
04-Sep-98	Orchard Hills WFP Raw Water	17/10L	169	ND/10L	0
04-Sep-98	Prospect WFP [illegible] Channel [illegible]	4/5L	80	10/5L	200
04-Sep-98	Prospect WFP Inlet to Contact Channel	7/10L	70	2/10L	20
04-Sep-98	[illegible] Ave, Terry Hills	2^	2	ND^	0
05-Sep-98	Warragamba Dam - 10m	[illegible]	4	[illegible]	0
05-Sep-98	Nepean WFP Raw Water	1/5L^	20	ND/5L^	0
05-Sep-98	Woronora WFP Raw Water	4/5L^	80	ND/5L^	0
05-Sep-98	Illawarra WFP Raw Water	2/20L^	10	ND/20L^	0
05-Sep-98	Macarthur WFP Raw Water	1/5L	20	36/5L	720
05-Sep-98	Warragamba Dam - [illegible]	4/20L	20	ND/20L	0
06-Sep-98	Woronora WFP Finished water	2	2	7	7
06-Sep-98	Prospect WFP Finished Water	ND	0	8	8
06-Sep-98	Prospect WFP Inlet to Contact Channel	ND/20L	0	12/20L	60
06-Sep-98	[illegible] St, Regents Pk [illegible]	13	13	ND	0
07-Sep-98	[illegible] Ave, [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
07-Sep-98	Warragamba Dam Pipeline WP1-1 & WP1-2 - Co	[illegible]	40	[illegible]	52
07-Sep-98	[illegible] Ave, Winston Hills	[illegible]	220	38/10L	380
07-Sep-98	Prospect Nth - Upper [illegible] composite	21^	21	26^	26
08-Sep-98	Warragamba Dam - Composite of [illegible] &	4/10L	22	[illegible]/10L	72
08-Sep-98	Warragamba Dam - Composite of [illegible] &	1/15L	7	[illegible]	27

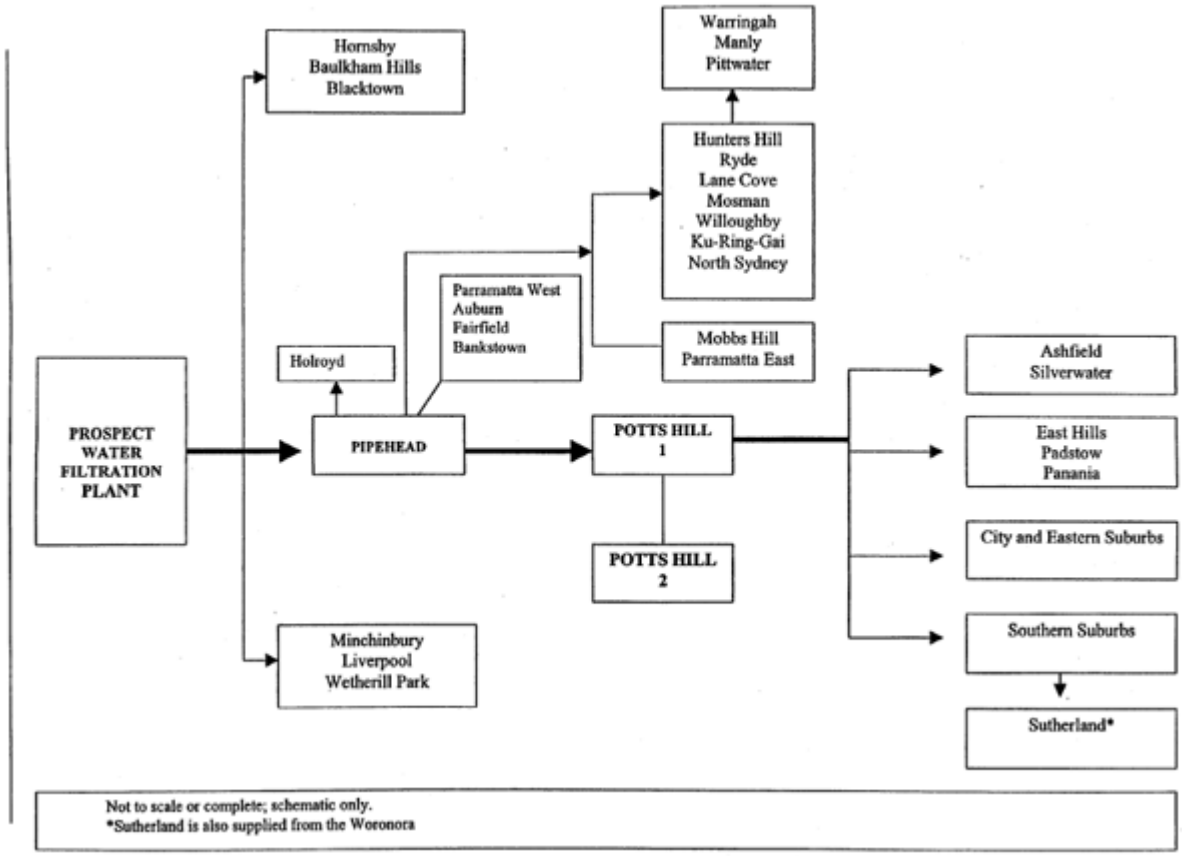
Date	Sampling Site Description	Crypto Count	Crypto adjusted (Number/100L)	Giardia Count	Giardia adjusted (Number/100L)
09-Sep-98	Prospect WFP Inlet to Contact Channel	[illegible]/20L	0	[illegible]/20L	55
09-Sep-98	Prospect WFP Finished Water	ND	0	12	13
09-Sep-98	Prospect WFP Finished Water	22	22	30	30
09-Sep-98	Cataract Dam at wall - 40m	9/8L	112	20/8L	250
09-Sep-98	Cataract Dam - 10m	14/10L	40	42/10L	420
09-Sep-98	Macarthur WFP Raw Water	29/8L	362	32/8L	400
09-Sep-98	Illawarra WFP Finished Water 40m d/s	1	1	ND	0
09-Sep-98	Warragamba Dam Pipeline WSP1-1 & HPW1-2 - Co	3	3	7	7
09-Sep-98	Upper Canal @ Prospect	49/4L	1225	78/6L	1300
10-Sep-98	Prospect WFP Inlet to Contact Channel	25/20L	125	58/20L	290
10-Sep-98	Cataract Dam at wall - Composite	42/8L	5250	125/8L	1562
10-Sep-98	Warragamba WFP Reservoir	41	41	174	185
10-Sep-98	Orchard Hills WFP Reservoir R205/R204	29	29	30	30
10-Sep-98	Prospect WFP Inlet to Contact Channel	29/20L	145	9/20L	45
10-Sep-98	Prospect WFP Finished Water	64	64	7	7
10-Sep-98	Cataract Dam - Depth Composite	33/10L	330	93/10L	930
10-Sep-98	Warragamba Dam Pipeline WSP1-1 & HPW1-2 - Co	33	33	35	55
10-Sep-98	Prospect WFP Finished Water	47	47	58	58
10-Sep-98	Prospect WFP Inlet to Contact Channel	109/20L	545	83/20L	415
10-Sep-98	Upper Canal @ Prospect	222/5L	4440	302/5L	6040
10-Sep-98	Warragamba WFP Reservoir	352	350	333	330
11-Sep-98	Woronora WFP Filtered Water	55	55	51	51
11-Sep-98	Warragamba Dam - 80m	145/10L	1450	75/10L	750
11-Sep-98	Nepean WFP Clear Water Tank	103	106	99	97
11-Sep-98	Macarthur WFP CP4 pH corrected filtered water	58	58	33	50
11-Sep-98	Orchard Hills WFP Reservoir R205/R204	202	208	305	385
11-Sep-98	Warragamba WFP filter composite [illegible]	242	242	408	408
11-Sep-98	Warragamba WFP Reservoir	193	195	214	224
11-Sep-98	Illawarra WFP Finished Water	141	141	137	137
11-Sep-98	Cataract Dam at wall - Composite	11/2L	550	64/8L	800
11-Sep-98	Prospect WFP Finished Water	38	59	32	32
11-Sep-98	Prospect WFP Inlet to Contact Channel	20/20L	105	45/20L	225
11-Sep-98	Warragamba Dam Pipeline WSP1-1 & HPW1-2 - Co	33/20L	165	33/20L	165
12-Sep-98	Warragamba Dam Pipeline WSP1-1 & HPW1-2 - Co	2	2	ND	0
13-Sep-98	Warragamba Dam Pipeline WSP1-1 & HPW1-2 - Co	10	10	ND	0

Date	Sampling Site Description	Crypto Count	Crypto adjusted (Chambers [illegible])	Giardia Count	Giardia adjusted (Chambers [illegible])
13-Sep-98	Prospect WFP Inlet to Contact Channel	17/20L	180	66/20L	330
13-Sep-98	Prospect WFP Finished Water	2	2	24	24
13-Sep-98	Warragamba Dam - Composite [illegible] - 50m	29/25L	128	84/15L	227
13-Sep-98	Warragamba Dam - Composite [illegible] - 45m	15/10L	59	11/20L	65
14-Sep-98	Upper Canal @ Prospect	5/10L	50	10/10L	100
14-Sep-98	Prospect WFP Inlet to Contact Channel	28/20L	129	39/20L	169
14-Sep-98	Prospect WFP Finished Water	2	2	7	7
15-Sep-98	Upper Canal @ Prospect	ND/20L	0	1/20L	6
15-Sep-98	Macarthur WFP [illegible] water	1	1	ND	0
15-Sep-98	Cataract Dam [illegible] - Composite	ND/10L	0	4/9L	47
[illegible]-Sep-98	Prospect Reservoir	ND/20L	0	1/20L	5
[illegible]-Sep-98	Warragamba WFP Research	9	2	ND	0
[illegible]-Sep-98	Upper Canal @ Prospect	2/10L	12	ND/15L	0
[illegible]-Sep-98	Upper Canal @ Prospect	2/12L	17	ND/12L	0
[illegible]-Sep-98	Woodford Dam	ND/11L	0	1/11L	9
[illegible]-Sep-98	Prospect WFP Finished Water	8	2	ND	0

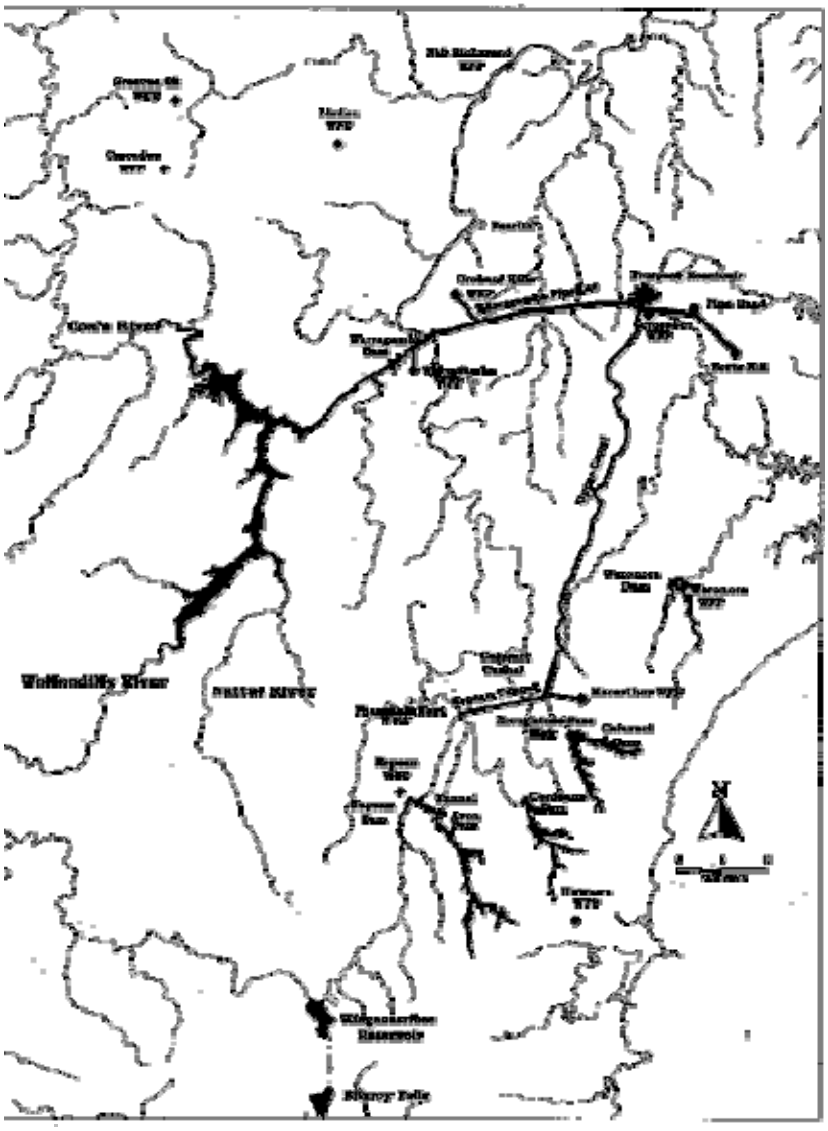
J: Warragamba and Upper-Nepean catchments



K: Diagram of the distribution system from the Prospect Plant



L: Major water filtration plants



M: Media Releases

Sydney WATER

media release

27 July 1998

Sydney Water Takes Quick Action on Water Issue

Sydney Water today announced it has taken quick action to deal with an identified potential problem in the water supply for a small section of the eastern edge of Sydney's central business district.

Managing Director Chris Pellett said extensive routine tests of the water system had found evidence of the naturally occurring organisms -- cryptosporidium and giardia -- in pipes supplying water to a two-kilometre square section of the eastern central business district near Hyde Park and The Domain.

"Sydney Water conducts rigorous water testing across its whole network and in this instance has identified an isolated incident," said the Managing Director.

"As a result, we've taken immediate action to clean and flush the water mains in this area, and to advise customers in the identified area to take precautions with their water."

Mr Pellett said Sydney Water had conducted extensive tests of the water supply system throughout Sydney and beyond the central business district and found no evidence of the micro-organisms in these supply areas.

"I can assure our customers in the Sydney, Illawarra and Blue Mountains regions that their water remains perfectly safe to drink."

Sydney Water is considering its work with NSW Health on this issue. The Corporation is conducting extensive further testing to ensure the system is clear. Results received so far today show no presence of the organisms.

Sydney Water will advise customers in the eastern CBD when the all clear is to be given. In the meantime, NSW Health advises customers in the area to boil their water for a minimum of one minute. Both NSW Health and the Corporation also advise that most commercial water filters do not remove the organisms and should not be relied upon.

Sydney Water has established a customer information line on 1800 644 922.

[illegible]

"Sydney Water is more than confident that it has identified and dealt with this matter promptly.

"Recent testing has shown the system within the CBD to be clean, but until extensive further testing reinforces that result, Sydney Water will continue to take the most cautious approach in the interest of public health."

For more information contact Rod Metcalfe on (02) 9350 5740

A Statement from NSW Health for Sydney Morning Herald 28th July 1998

Over the past year NSW Health has conducted intense active surveillance for evidence of disease which could be attributed to cryptosporidium in drinking water. So far no disease has been detected.

During the weekend NSW Health carefully monitored reports of water testing from Sydney Water.

On Monday new evidence came to light showing the source of the organisms was possibly due to a problem with the pipes that allowed contaminated water to be sucked in.

It was at that point it was decided a warning should be issued as a precaution.

No relationship has been established between finding cryptosporidium in drinking water at any level (in Australia or elsewhere) and effects on human health.

That means a high level versus a low level does not necessarily indicate an increased risk.

This is also supported by a large survey of treated North American water supplies which showed that despite the presence of cryptosporidium there was no evidence of human disease.

The lack of association between cryptosporidium in drinking water and human illness may be because the organisms are killed during water treatment processes.

Two-day silence on tainted city water

By ANNE DUNCAY

Health and water authorities waited two days before getting public alert levels of poisonous bacteria and cancer-causing chemicals into tainted city drinking water.

Sydney Water issued a press release at 3 pm on Monday warning any residents within a small area of the suburb of College Street to boil water for all uses before using it.

But tests first revealed the levels of the parasites in the water were very high almost 48 hours earlier, on Saturday.

On Saturday, high levels of both parasites – which can cause severe gastrointestinal illness in healthy people and have fatal consequences for babies, the elderly and people with AIDS – were found in Woolcott Reservoir and College street mains.

Sydney Water and water health did not give to discuss early media publication of the results.

The Opposition Leader, Mr Collins, said the "extremely alarmed public" should be Sydney's right to expect prompt warnings before the weekend.

"The real question is why it took the Government two days to release this information," he said.

A Sydney Water spokesman said it would be another day before the results of further tests

would be known.

Sydney Water's deliberately misleading the public."

Cryptosporidium and giardia are normally found in human and animal excrement. Illnesses from both parasites are caught when the organisms are ingested.

The giardia levels found on Saturday were 200 to 300 cysts of the parasite per 100 litres of water, while the Cryptosporidium levels were normal, or in excess of 200 litres. Normal levels for both parasites in drinking water supplies are between zero and one per 100 litres. Normal levels readings were registered at least five days over the weekend.

The area affected was bounded by Crown, Oxford, and Campbell streets and the Royal Botanic Gardens.

The Sydney Water spokesman said pipes in the area were locked and the standby for possible contact was 4pm.

Testing took 24 hours and there was an "acceptable" test in Australia of what to do, he said.

A NSW Health spokeswoman said the illnesses had been reported and the precautionary warning was issued on Monday when the test results were available.

"The Monday press release came in light showing the source of the organisms was possibly due to a problem with equipment [the filtration] contamination] seemed to be resolved by," she said.

"The relationship has been established between Sydney Cryptosporidium as drinking water at very low to diarrhea or diarrhoea, and others on human health."

A similar outbreak in Milwaukee, USA, the Duncan said, was the outbreak was "unusual and highly unfavorable to find in a filtered [treated] water."

Seven Sydney pools were temporarily closed after the Australian-Japanese pentathlon championships in March.

"B"

Sydney WATER

Investigations are [illegible] the source of the giardia infection [illegible] from [illegible] water

29 July 1998

~~URGENT~~ PUBLIC ANNOUNCEMENT

(1) Extensive testing by Sydney Water Corporation has identified the presence of the micro-organisms Giardia and Cryptosporidium in parts of Sydney's water supply.

A batch of water containing these organisms in the Eastern Sydney CBD was identified late last week.

A second batch has now been identified [illegible]

~~In conjunction with NSW Health, Sydney Water is issuing this precautionary alert for all areas of Sydney [illegible]~~

Residents of the affected area are advised to boil drinking water for one minute and allow it to cool naturally before drinking. ~~[illegible]~~

Normal hot water can be used for bathing, dishwashing and cleaning cooking utensils, but [illegible]

Sydney Water believes it has identified the source of the contamination and is working to [illegible] supply to quality as [illegible]

~~The micro-organisms can cause a severe diarrhoea. People concerned should seek professional medical advice.~~

Sydney Water will ~~keep the community informed through the media~~ continue monitoring a testing program throughout the metropolitan area

The Sydney Water Hotline is available: 1800 [illegible] (24 hours)

Media Information: Rod Mulcahy/Colin Judge 02-[illegible] Pager 02-[illegible]

which could affect

The giardia can cause stomach upset and may require seeking professional medical advice.

Head Office:

115-123 Bathurst Street, Sydney, NSW 2000, Australia PO Box A53, Sydney South, NSW 2000, Australia

Phone [illegible]

SYDNEY WATER CORPORATION LIMITED

Sydney
WATER

29 July 1998

PUBLIC ANNOUNCEMENT

Extensive testing by Sydney Water Corporation has identified the presence of the microorganism Giardia in parts of Sydney's water supply.

A batch of water containing the organism in the Eastern Sydney CBD was identified late last week.

A second batch has now been identified which could affect an area East of Bankstown - Silverwater, South of the Harbour and North of the Georges River.

Residents of the affected areas are advised to boil drinking water for one minute and allow it to cool naturally before drinking.

Sydney Water will advise as soon as the water supply is clear and further precautions become unnecessary.

Normal hot water can be used for bathing, dishwashing and cleaning cooking utensils.

Giardia can cause stomach upsets and may require seeking professional medical advice.

Sydney Water will continue monitoring and testing throughout the metropolitan area.

The Sydney Water Hotline is available: 1800 644 522 (24 hours)

Media Information: Rod Metcalfe/Colin Judge
02-9350-5590/02 9350-5151
Pager 01 - 9966-2744

Head Office
[illegible] Bathurst Street Sydney, NSW 2000, Australia PO Box [illegible], Sydney South NSW [illegible] Australia
Phone [illegible] Sydney
SYDNEY WATER CORPORATION [illegible]

Sydney
WATER

20

30 July 1998

SOURCE OF CONTAMINATION CONFIRMED

The source of the organisms found in Sydney's water supply has been identified and action is now taking place to control the presence of Giardia and Cryptosporidium.

The Managing Director of Sydney Water, Mr Chris Fullen, said tonight the outlet at the Prospect Water Treatment Plant has been shut off and water for Sydney was being drawn and distributed from Warragamba Dam so that water to Sydney will completely bypass the Prospect Water Filtration Plant.

Mr Fullen said that results of testing undertaken today and completed this evening indicated a Giardia presence at Palm Beach. Water supply leading to this area had previously tested clear of both organisms.

Mr Fullen said that having now found the source of contamination and received further results of testing, Sydney Water and NSW Health had decided that all Sydneysiders should boil tap water for one minute prior to drinking.

This is expected to be for a period of approximately 48 hours. Continuous testing will take place until an all-clear can be given.

Residents of the Blue Mountains, Penrith, Richmond/Windsor, Campbelltown and the Illawarra are not affected as their water does not travel through Prospect.

Schools, hospitals, nursing homes and child care centres that were not in the previous identified area are tonight being notified of this city-wide alert.

The Director of Education, Dr Ken Boston, has asked parents that their children take their own drinks to school tomorrow.

The Prospect Plant and its downstream pipes are now being treated to clear Giardia and Crypto organisms.

An intensive audit of the plant and its treatment and monitoring systems is now underway. The results will be released publicly and sent to the independent inquiry announced by the Premier today.

Sydney Water and NSW Health have released the following information:

- Boil water for at least one minute on a rolling boil. For automatic shut-off kettles the button should be held down for at least one minute
- Boiled water should be left to cool then put in the fridge in a clean container with a lid

/2

Head Office

115-123 Bathurst Street, Sydney, NSW 2000, Australia PO Box 500, Sydney South, NSW 2001, Australia

Phone [illegible] DX 14 Sydney

SYDNEY WATER CORPORATION LIMITED ACN [illegible]

- Boiled water should be used for drinking, cooking, making ice, personal hygiene, pets' drinking water and where there is a risk of ingestion for:
  - washing hands
  - cleaning teeth
  - gargling
  - with small children - face washing
  - wash toys and children's utensils.

A customer hotline is available on 1300 884 322

news release

Minister for Urban Affairs and Planning
Minister for Housing

30 July 1998

ACTION TAKEN TO MAKE DRINKING WATER SAFE

Sydney Water has taken immediate action to make drinking water safe for residents who could potentially be affected by the presence of the microorganism Giardia in parts of Sydney's water supply.

The Minister for Urban Affairs and Planning, Mr Craig Knowles, said the problem is believed to be related to a water source coming down the Upper Canal to the Prospect Treatment Plant.

Mr Knowles said the following action has been taken to protect the public:

- the Upper Canal has been turned off to isolate it from Sydney's water supply;
- chlorine levels have been increased throughout Sydney's water system to help kill off any traces of Giardia;
- only Warragamba water is arriving at the Prospect Treatment Plant;
- all schools, hospitals, nursing homes, community health centres and dental hospitals in the affected area have been notified and advised to boil all water for at least one minute before drinking.

Sydney Water detected the traces of Giardia around 9pm last night and immediately notified health authorities. A public health announcement was released soon after and testing was continued.

Testing and monitoring is also continuing to be conducted throughout Sydney's water system.

The Managing Director of Sydney Water, Mr Chris Pelloli, said preliminary testing had shown traces of Giardia in the system between Prospect Filtration Plant and the city, but that detailed test results were not yet available.

He said Sydney Water had released a list of all affected suburbs to media and community outlets will continue to keep the public updated on testing procedures and will advise immediately the water supply is clear.

Further information: Helen Willoughby 9228 4499; 0419 239 178

Affected Suburbs: (the suburbs in this list include the variations of North, South, East, West, Bay, Heights etc)

Abbotsford
Alexandria
Allawah
Annandale
Arncliffe
Ashbury
Ashfield
Auburn
Balmain
Banksia
Banksmeadow
Bankstown
Bardwell Park
Beaconsfield
Belfield
Bellevue Hill
Belmore
Beverley Hills
Beverley Park
Bexley
Birchgrove
Blakehurst
Bondi
Bondi Junction
Botany
Brighton-le-Sands
Bronte
Burwood
Cabarita
Camperdown
Campsie
Canada Bay
Canterbury
Carlton
Carss Park

Centennial Park
Chifley
Chippendale
Chiswick
Chullora
City of Sydney
Clovelly
Concord
Connells Point
Coogee
Croydon
Croydon Park
Daceyville

Darling Point
Darlington
Darlinghurst
Dawes Point

Diamond Bay
Dolls Point
Double Bay
Dover Heights
Drummoyne
Dulwich Hill
Earlwood
Eastlakes
Edgecliff
Elizabeth Bay
Enfield
Enmore
Erskineville
Five Dock
Flemington
Forest Lodge
Glebe
Greenacre
Haberfield
Hillsdale
Homebush
Hurlstone Park
Hurstville
Kensington
Kings Cross
Kingsford
Kingsgrove
Kogarah
Kyeemagh
Kyle Bay
La Perouse
Lakemba
Leichhardt
Lewisham
Lidcombe

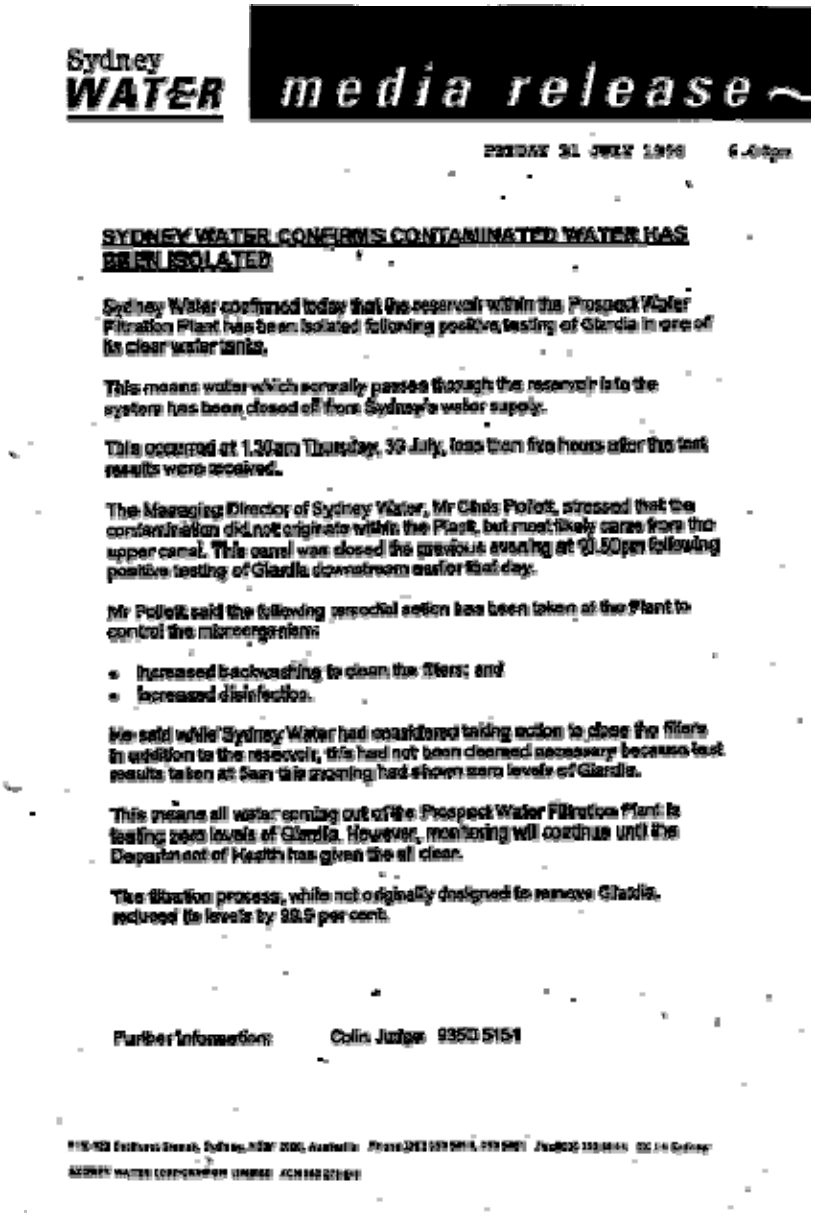
Lilyfield
Little Bay
Lugarno
MacDonaldtown
Malabar
Maroubra
Marrickville
Mascot
Matraville
Millers Point
Mortdale
Mortlake
Mt Lewis
Narwee
Newtown
Oatley
Penshurst

Monterey
Paddington
Padstow
Pagewood
Peakhurst
Petersham
Phillip Bay
Point Piper
Port Botany
Potts Point
Punchbowl
Pyrmont
Ramsgate
Randwick
Redfern
Revesby
Rhodes
Riverwood
Rockdale
Rodd Point
Rookwood
Rose Bay
Rosebery
Rozelle
Rushcutters Bay
Russell Lea
Sandringham
Sans Souci
Silverwater
St Peters
Stanmore
Strathfield
Summer Hill
Surry Hills
Sutherland
Sydenham
Tamarama
Tempe
The Rocks
Turrella
Ultimo
Undercliffe
Vaucluse
Woollahra
Waterloo
Watsons Bay
Waverley
Wiley Park
Woolloomooloo

Zetland

Below is a list of Local Government Areas where the premises of Ghazis has been declared.

Ashfield
Auburn
Bankstown
Botany
Burwood
Canterbury
City of Sydney
Concord
Drummoyne
Hurstville
Kogarah
Leichhardt
Marrickville
Randwick
Rockdale
South Sydney
Strathfield
Sutherland
Waverley
Woollahra



Sydney WATER media release

FRIDAY 31 JULY 1998 6.40pm

SYDNEY WATER CONFIRMS CONTAMINATED WATER HAS BEEN ISOLATED

Sydney Water confirmed today that the reservoir within the Prospect Water Filtration Plant has been isolated following positive testing of Giardia in one of its clear water tanks.

This means water which normally passes through the reservoir into the system has been closed off from Sydney's water supply.

This occurred at 1.30am Thursday, 30 July, less than five hours after the test results were received.

The Managing Director of Sydney Water, Mr Chris Pollett, stressed that the contamination did not originate within the Plant, but most likely came from the upper canal. This canal was closed the previous evening at 10.30pm following positive testing of Giardia downstream earlier that day.

Mr Pollett said the following remedial action has been taken at the Plant to control the microorganism:

- Increased backwashing to clean the filters; and
- Increased disinfection.

He said while Sydney Water had considered taking action to close the filters in addition to the reservoir, this had not been deemed necessary because test results taken at 5am this morning had shown zero levels of Giardia.

This means all water coming out of the Prospect Water Filtration Plant is testing zero levels of Giardia. However, monitoring will continue until the Department of Health has given the all clear.

The filtration process, while not originally designed to remove Giardia, reduced its levels by 99.5 per cent.

Further information: Colin Judge 9350 5151

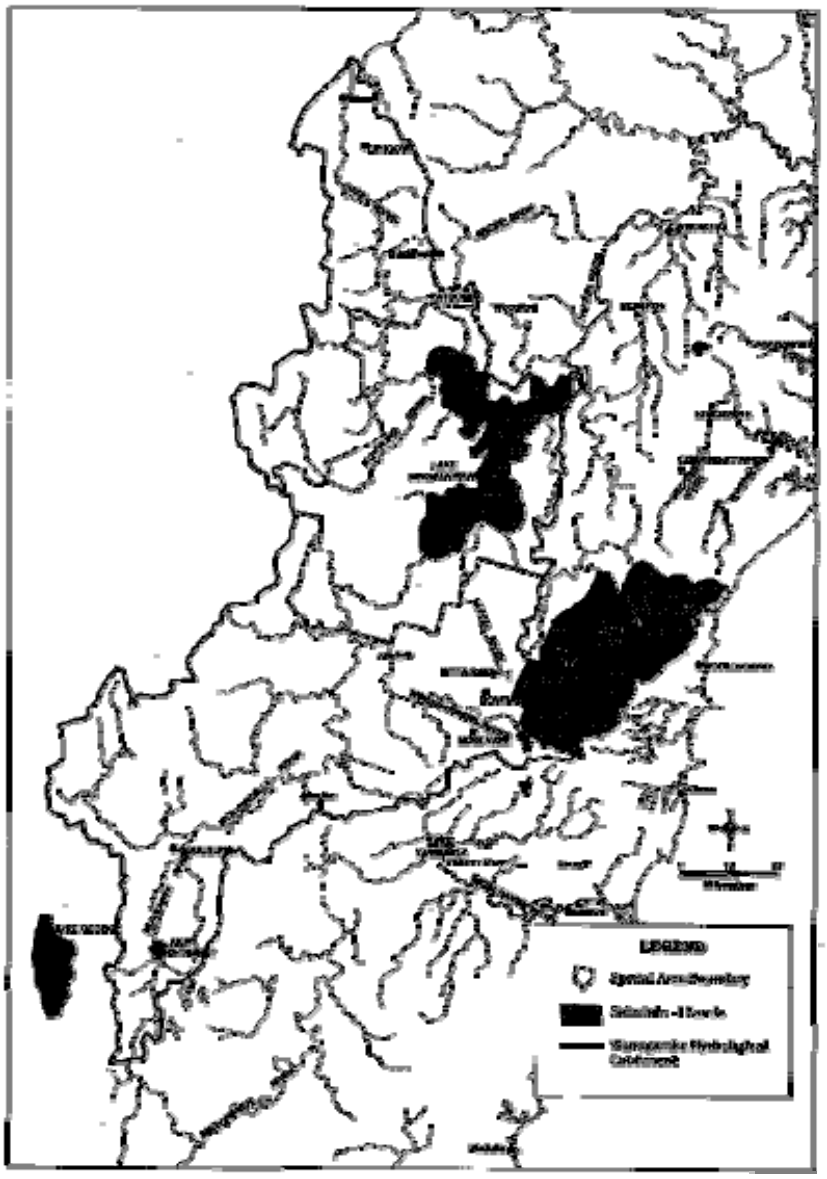
[redacted]

N: List of expert panel members

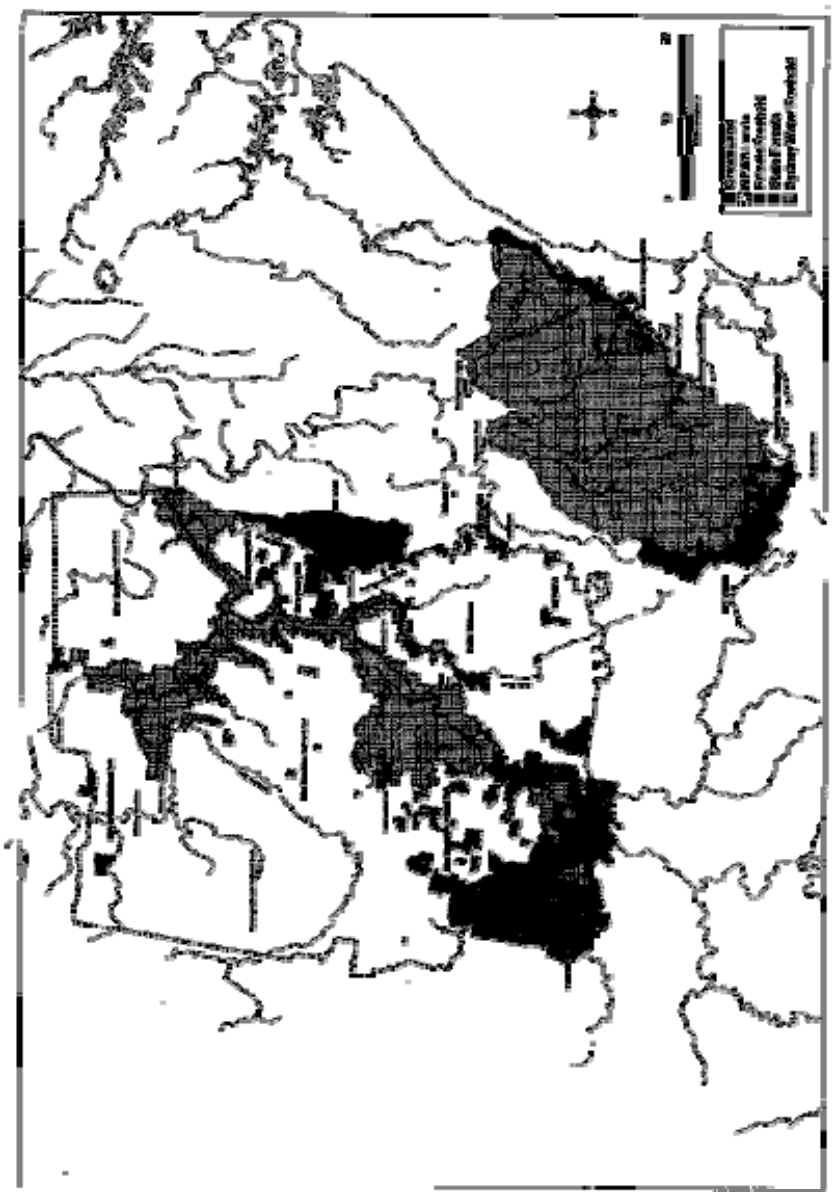
Assoc Prof Bell	Syd	Executive Medical Director	South Eastern Area Laboratory Services
Assoc Prof Ferson	Mark	Director and Medical Officer of Health	South Eastern Sydney Public Health Unit
Prof Sorrell	Tania	Professor of Clinical Infectious Diseases, University of Sydney	University of Sydney at Westmead Hospital

			and Director of the Centre for Infectious and Microbiology Westmead Hospital	
Dr	Walker	John	Senior Lecturer in Parasitology	University of Sydney at Westmead Hospital
Prof	Gilbert	Lyn	Director of Clinical Microbiology	Centre for Infectious Diseases and Microbiology Laboratory Services ICPMR
Dr	Veal	Duncan	Senior Lecturer Macquarie University	School of Biological Sciences, Macquarie University

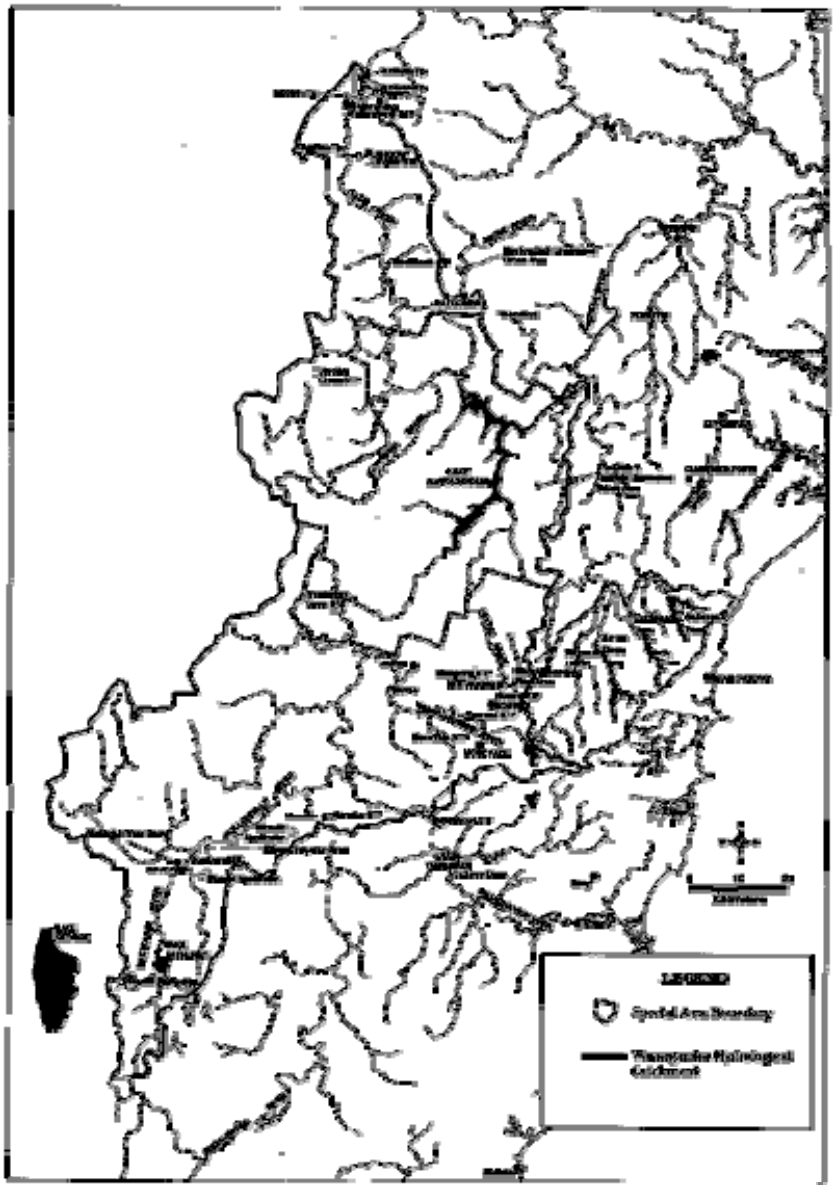
O: Sydney's water supply catchments



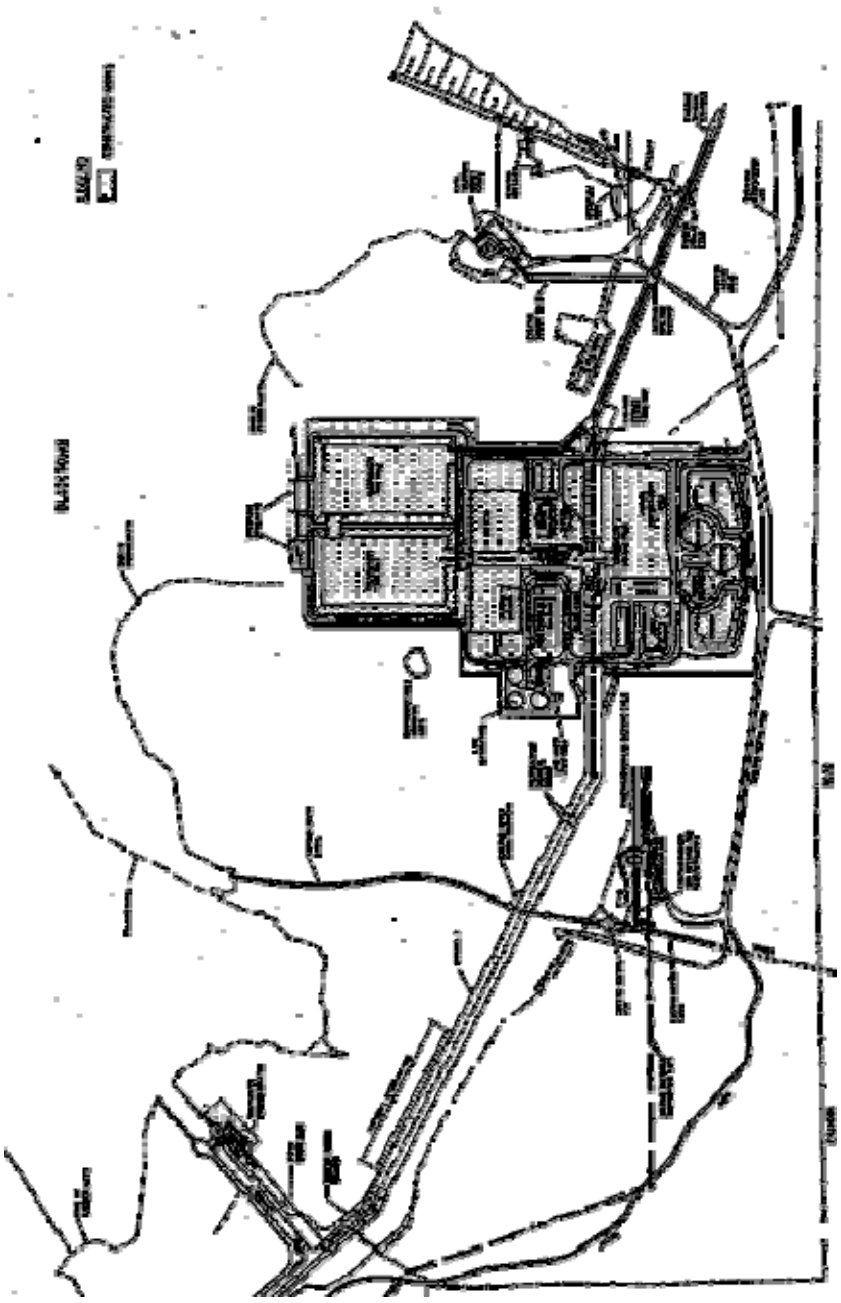
P: Tenure details in Inner Catchment



Q: Possible Sources of contamination in the catchments



R: Diagram of the Prospect Plant



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Source: Sydney Morning Herald 29 July 1998